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Vol. 28 : No. 195 DECEMBER, 1961 Price 2/6

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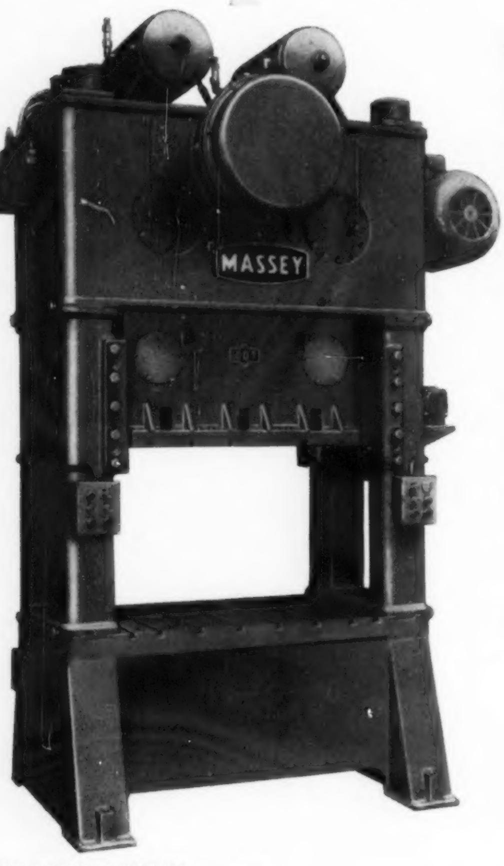

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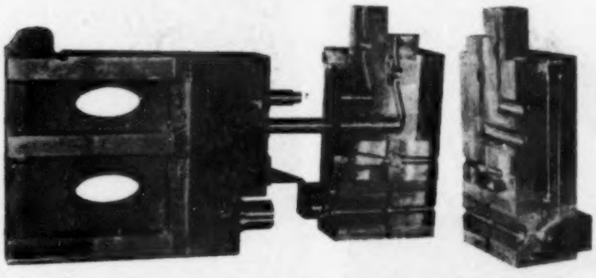

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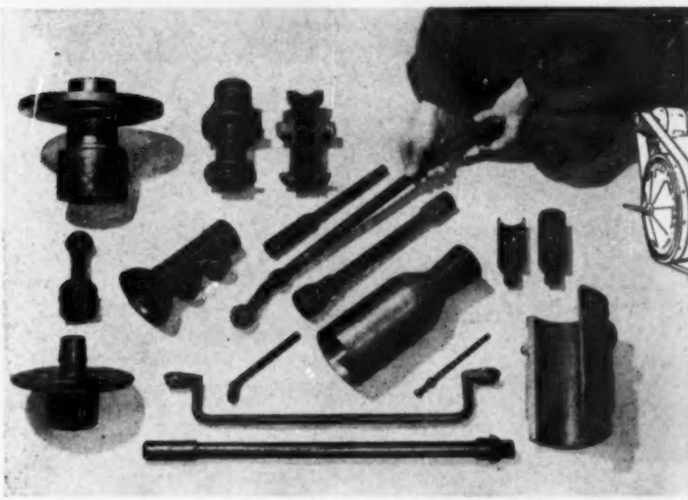

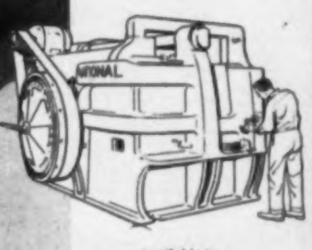

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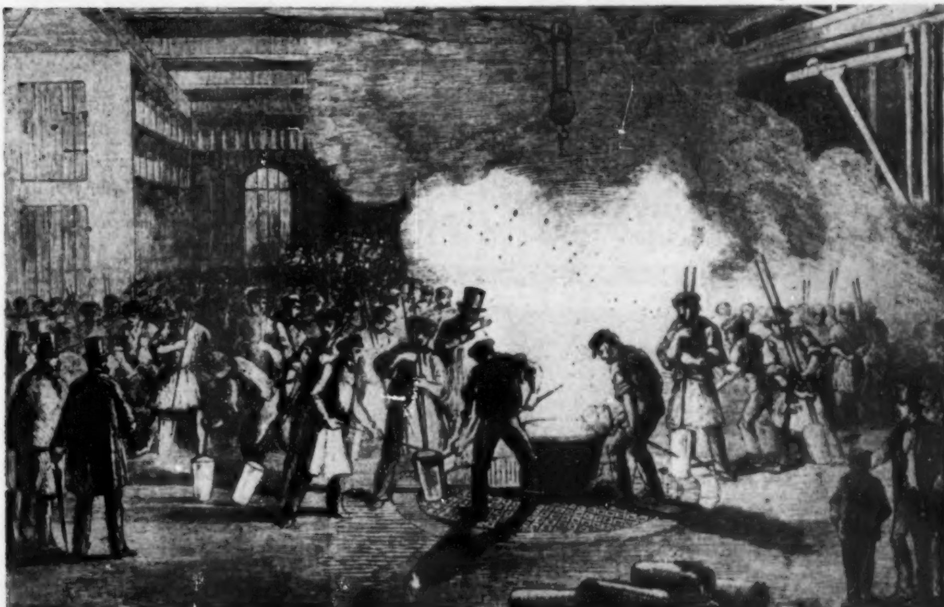
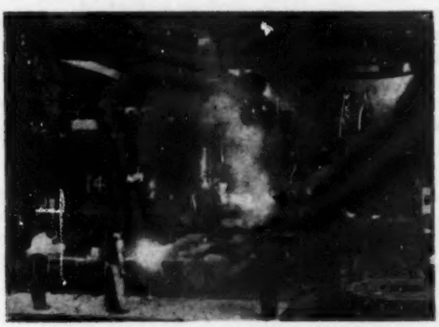


Casting a 75in. diameter Bell for San Francisco in 1859.



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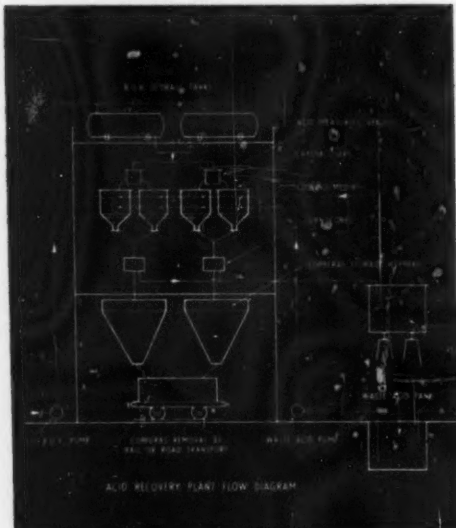

The sulphuric acid regeneration plant recently installed by John Thompson (Dudley) Ltd., at the new Brinsworth Mill of Steel, Peech & Tozer, is probably the largest of its kind in this country. The complete plant is capable of treating all spent pickle liquors from the continuous strip lines in the mill, and provision has been made for doubling the capacity of this plant at a future date to meet the demand when the mill is working at maximum capacity.

In addition to the above there is installed a large neutralisation plant for dealing with all waste effluents from the continuous strip lines. These plants are larger than any likely to be required in the wire industry, but the same principles are applicable to plants on a smaller scale and of smaller capacity, which would be of considerable interest and value to the medium and large wire mill using sulphuric acid.

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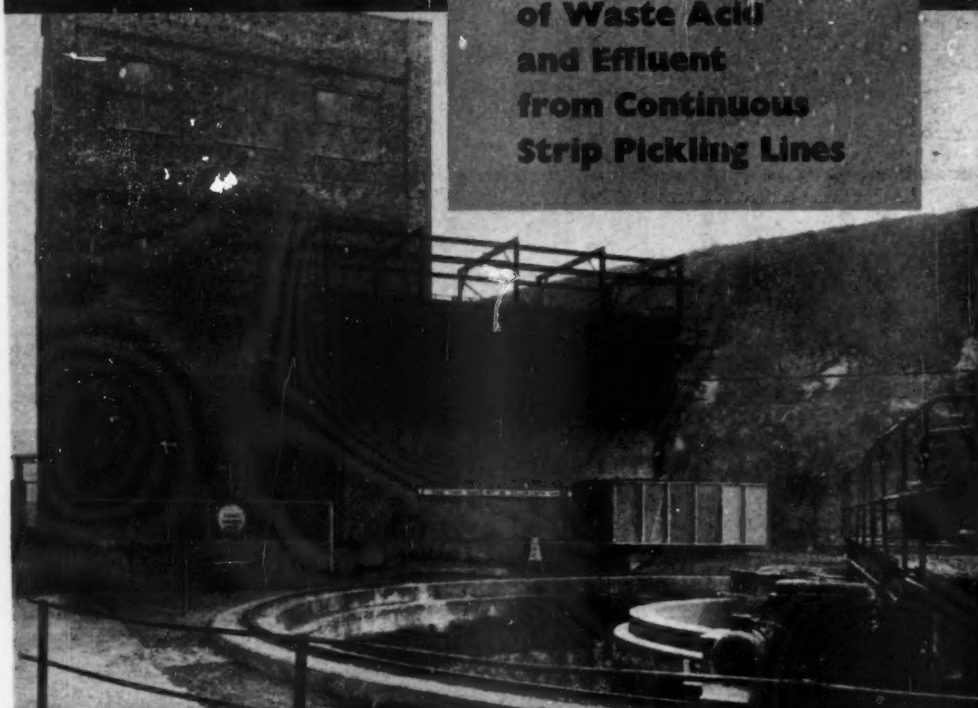

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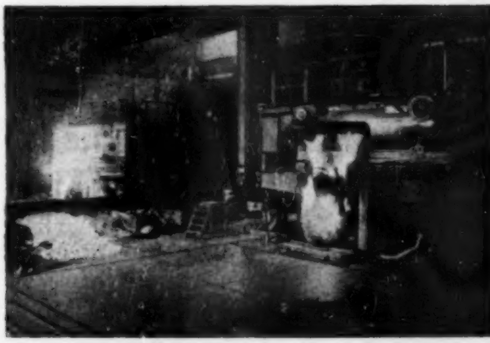

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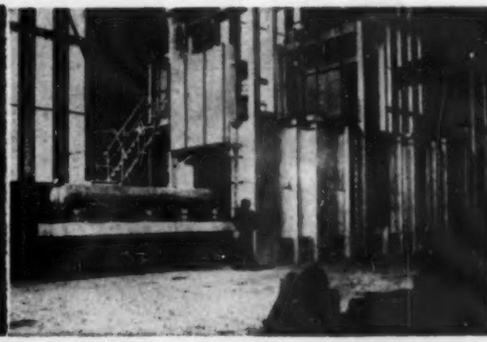

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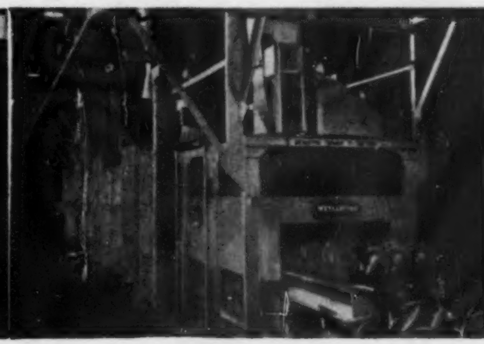

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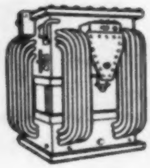
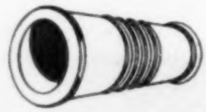


from transformers

to bellows



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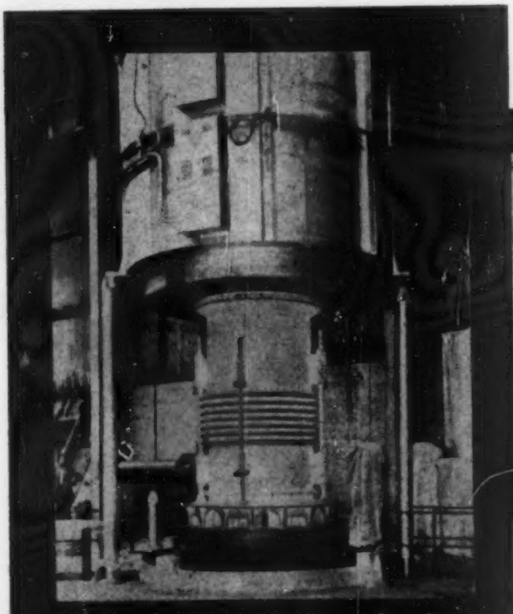

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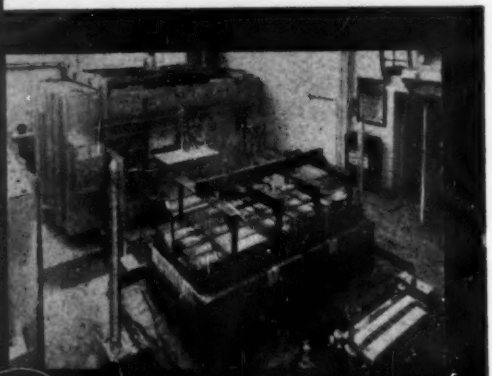

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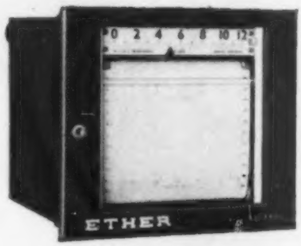

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December, 1961

Vol. 28, No. 195

metal treatment

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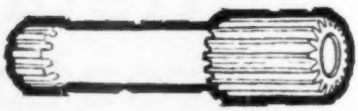
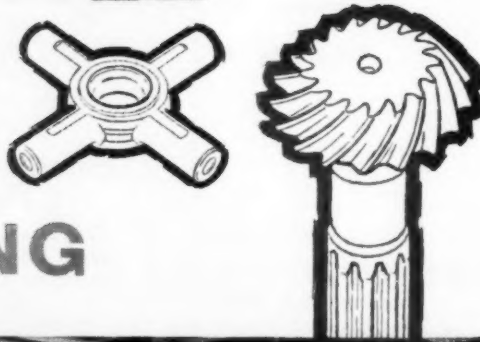
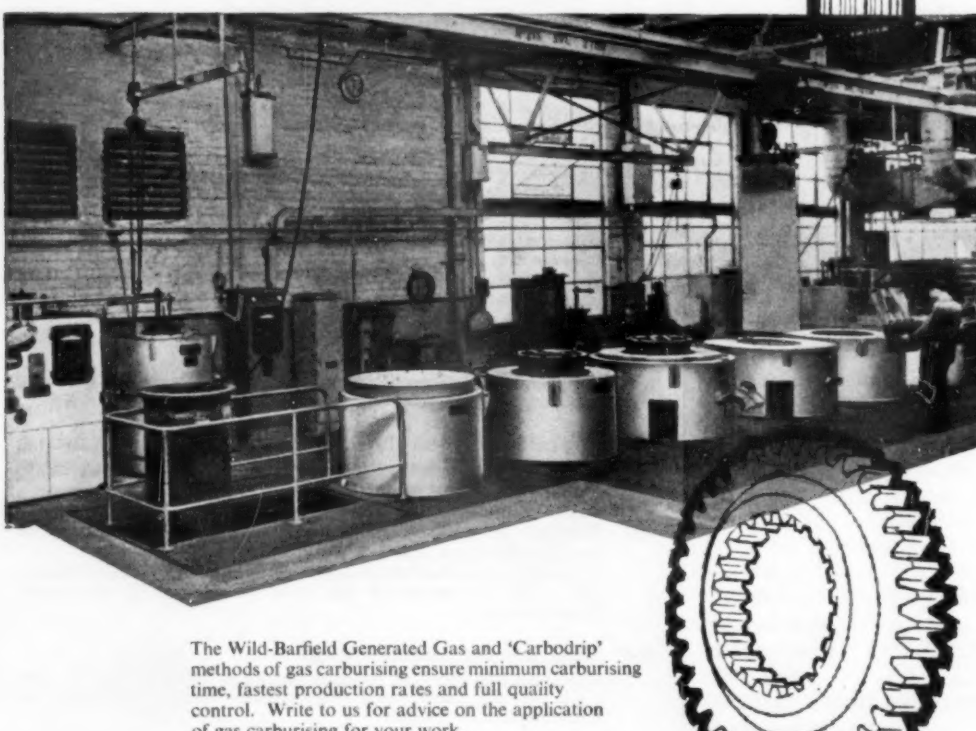
CONTENTS

This journal is devoted to metals—ferrous and non-ferrous—their manufacture, properties, heat treatment, manipulation, testing and protection, with research work and development in all these fields







Steel and Europe

Now that the decision has been taken for Britain to apply for membership of the European Communities, it is time to consider the implications for particular industries. Mr. C. R. Wheeler, C.B.E., president of the British Iron and Steel Federation, speaking at a recent Iron and Steel Institute meeting, said that the great weight of opinion in the British iron and steel industry welcomed the Government's decision to apply for full membership of the European Communities. It was hoped that entry into Europe might eventually bring still further gains through its revitalizing effect on the economy as a whole. Mr. Wheeler emphasized, however, that the essential thing was now to increase the steel industry's capacity to sell steel—both by improving the cost efficiency of plants, and by improving sales machinery.

Mr. Wheeler then considered some of the detailed questions raised. The British iron and steel industry would not disappear as a unit any more than the German or French steel industries had disappeared. The steel federations of the six present-day Community members had taken on new and important functions since the opening of the Common Market, and our Federation might possibly follow the same course. This did not imply that the central arrangements of the industry would all continue unchanged in their present form. The position of the industry fund generally and of the central importing arrangements in particular would need to be carefully considered.

The industry was of the opinion that Britain's entry into ECSC would require an urgent reassessment of national fuel policy. Since the opening of the ECSC, the pithead price of the British coking coal bought by the industry had gone up nearly 60%, whereas the prices of Community coking coal have not risen by more than 16%. The Community steelworks which were being developed on coastal sites were able to enjoy large imports of cheap American coal on a regular basis whereas British coastal plants were forced to rely on home supplies which were, in one case, some 30*s*. a ton dearer. British steel producers could not be expected to compete in a freer Community market with the handicap of excessive fuel costs still riveted upon them. If the Government decided to place British steelmakers in more competitive conditions *vis-a-vis* their end products, then the Government must equally ensure more competitive conditions *vis-a-vis* fuel supplies.

There could be no doubt that radical changes faced the British steel industry. We had to expect at some reasonably early date to have to abandon a system of uniform zonal delivered prices and in its place to introduce an ECSC system, with reliance on published basing point prices, and with regulated price alignment as a further important innovation. The ECSC pricing system required the charging and publication of non-discriminatory transport rates. Here we were in the hands of the British Transport Commission and the Government. This was a matter of great importance for future rate-fixing policy in the British transport system as a whole.

A particular problem for the steel industry arose out of the structure of British taxation in the light of the ECSC's present pricing rules. In Britain none of the tax burden falling on the steel producers arose in the form of turnover or sales taxes, and so our position in the Community would seem likely to be even worse in this respect than that of any other country.

In conclusion, Mr. Wheeler said that the industry wanted to be assured that it would be allowed to compete on equal terms, and therefore wanted to see Government policy reviewed in certain important particulars in order to make such equality possible. Secondly, we all wanted to ensure that such competition was fair competition and kept to the rules.

Russian forging journal

Abstracts from the Russian forging journal—'Kuznechno-Shtampovochnoe Proizvodstvo,' April, 1961, **3.** *This is the third year of this journal devoted specifically to forging. Short abstracts of the more important articles are given in* METAL TREATMENT *each month.*

Cold rolling of the thread on long screws. M. M. VOLKOV. Pp. 1–5.
A description is given of the oblique skew rolling of coarse module threads on long screws for the conveyor mechanism of tube cold rolling mills. Theory and practice and the calculation of the working parameters and setting of the mill are also outlined. The technique produces considerable saving of metal, reduction in labour and plant capital costs, and an improvement in the accuracy and surface quality of the threads produced and in their fatigue strength.

The bending moment during the plastic flexure of sheet. M. I. PRUDNIKOV. Pp. 6–8.
The results are given of a theoretical investigation of the problem of the determination of the value of the bending moment, aimed at a relatively accurate and acceptably accurate equation. Calculated and experimental data show satisfactory agreements.

An investigation of the plastic properties of stainless steels during mechanical working. N. N. KORNEEV, G. M. MOROKHOVETS, F. I. FILATOV and V. P. MANYCH. Pp. 9–12.

Upsetting of tubes. N. M. ZOLOTUKHIN and V. YA. MIL'CHEVSKII. Pp. 13–15.
A machine is described for the upsetting of oil drill pipes in one operation by a continuous consecutive method in a calibrating ring without dies.

Extrusion stamping/forging of the rotating cam of the GAZ-63 automobile. I. E. GUTKIN. Pp. 15–18.
Production of the hollow pivot journal of this cam is described, on a 1600 horizontal press on which the upsetting is carried out in three operations.

Press equipment for the production of electrically welded tubes. A. Z. FRIDMAN, V. YU. PRISHCHEPO and R. S. KITAIN. Pp. 18–23.
The presses of the electric fusion weld mill at the Chelyabinsk works are described.

Experimental investigations of the strains and deformations in the basic components of crank drive presses. D. M. ABAKSHIN. Pp. 23–30.
The research shows that the rigidity of all-welded columns is greater than that of cast-iron assembled columns, and that all-welded columns are 30–38% lighter. The deformation of the former is about 20% of the overall deformation of the press, while the figure is 30–40% for the latter. The deformation of the crank drive mechanism represents about 60–70% of the total and is the weakest part, and the best way to improve the rigidity of a press is to increase the rigidity of the weakest component of this part of the press.

Increasing the strength of fillet unions of cylinders with flanges. B. A. MOROZOV, V. V. VASIL'EV and V. YA. LYUBIMOV. Pp. 31–32.
These unions are a weak point on steam-hydraulic presses, due to the development of fatigue cracks in the area of the fillet with subsequent fracture of the flange. A new method is suggested for calculations of the stresses in the transition cross-sections from the cylinder to the flange. This leads to a change in the design of the main cylinder of such presses, which has been found in practice to increase the working life.

A two-position cold upsetting press in a new automatic line. A. N. GLADKIKH and N. I. MASLENNIKOV. Pp. 32–35.
The cold upsetting press is a single-stroke press in a line producing bolts with a mechanically worked hexagon head at the 'Red Etna' Works, which also includes a knurling machine. The press is described in detail.

Consumption of electrical energy for the induction heating of billets in forge shops. N. V. BELYAEV. Pp. 36–39.
An examination is made of the specific consumption for the heating of typical forging billets for common engineering parts, based on many years' operational experience at a Russian works, and also of the factors influencing such consumption.

Mechanization of the preparatory section of a press shop. L. S. SAGATELYAN and L. M. TSIRIK. Pp. 39–41.
Information is given concerning lift tables for guillotine shears and removal/conveyor mechanisms for sheet billets.

Hot stamping of covers for sundry plant from welded packet billets. B. N. SHEVELKIN. Pp. 42–43.
Stamping of elliptical thin-walled covers from carbon sheet presents great difficulties where the

continued on page 486

Production of mechanically-worked components from special alloys of limited forgeability

DR. ZDENĚK EMINGER and V. PAUR

A method is described which makes possible the production of components with properties intermediate between forgings and castings. In particular, it makes possible the forging of alloys of limited forgeability by using as-cast shapes as the initial material for the forging. The method was first given in 'Hutnické Listy,' 1960, **15** (9). *The authors are at the Lenin Works at Pilsen*

THE PRODUCER OF creep-resistant materials intended for the manufacture of structural components of gas turbines for aircraft, locomotives and stationary engines is presented with conditions which become proportionately more arduous in accordance with the increasing demand of the designer to raise their working temperatures, loads and economic period of service. Today, the required materials must be structurally stable, not subject to embrittlement, chemically resistant to an active medium of combustion gases, and creep-resistant at temperatures from 600–1,000°C. At the same time the materials, for instance in stationary combustion turbines, must maintain suitable properties for five to ten years.

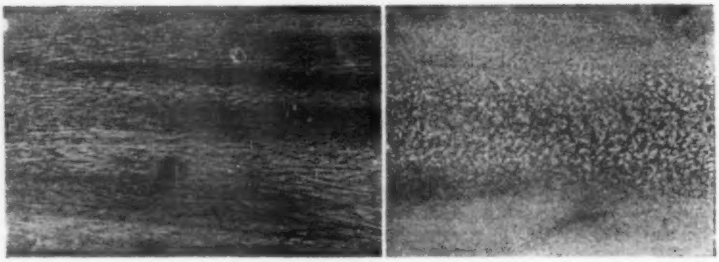
These demands can be met only by special austenitic alloys. The main component of such material destined for service at high temperatures must have as high a melting point as possible in order to withstand the thermally activated actions of the mobility of the atoms. Since both the economic and the technological aspects enter into consideration for the choice of the chemical composition, nickel and cobalt form the main components of these alloys. Apart from these, iron also enters into consideration. But hitherto it has been used only exceptionally for development, at the Lenin works,[1] *e.g.* in alloy VZÚ 60.

The greatest use is made of nickel-base alloys, primarily because nickel by its close-packed cubic structure, which is unchanged from normal temperature up to the melting point, affords the assumption that very high creep resistance will be attained. By comparison with Co and Fe, nickel also has very high resistance to oxidation at high temperatures.

It may be considered that the basis of this group of materials are Ni-Cr alloys, which normally contain about 20% Cr. Research work during recent years has led to the finding that an improvement in the properties of austenitic alloys can be obtained by further complex alloying. The importance of complex alloying can be perceived in elements which form carbides, thus strengthening the basic alloy. For elements which are in solid solution in the matrix, the hypothesis has been propounded that the greater number of atoms of varying dimensions, distributed in the crystal lattice, will place greater obstacles in the path of the dislocation movements than would be presented by a structure with only two different types of atom.[2]

As the most important alloying elements at the present time we may indicate Ti and Al, which form hardening phases: the intermetallic compound of stoichiometric proportions, Ni_3Ti (η-phase) and the compound Ni_3Al (γ'-phase) with a widely variable composition, which is isomorphous with the γ solid solution. Apart from these elements, use is made of W, Mo and also, in small quantities, B, Zr and other elements.

Today, there exist a great number of special NiCr and CoCr alloys, modified with Al, Ti, Mo, W, B, Zr, etc., in very different proportions and quantities. In these alloys iron is for the most part considered to be an impurity (max. $<3\%$). Exceptionally it is used as an alloying addition up to 15%.[1]



a b

1 *Comparison of the character of normally produced rolled billet* **a** *and a billet cast into water-cooled moulds* **b: a** *fibrous structure —mechanically-worked material;* **b** *granular structure—cast material (moderately reduced)*

The chemical composition of the individual alloys is chosen in such a way as to ensure the attainment of the highest possible values required for the operation of blades, discs, nozzles or jets, flues and other components of gas turbines, for instance. Often the situation arises where the addition of elements or combinations of elements acting favourably for instance in relation to creep resistance, impact strength or resistance to embrittlement, at the same time act very unfavourably on certain technological factors, for instance, castability, forgeability, weldability, etc. Hitherto it has been possible to produce either castings or forgings from these alloys. In the following paper we shall mention a basically new production process, which in certain instances makes it possible to employ alloys with even very limited forgeability, whose properties in the as-cast state do not completely satisfy requirements.

Cast and forged states of alloys

In many instances it seems economic to change over from hammer and press forgings to castings. This change-over, however, can only be made if the casting fulfils all the demands placed on it in service. In our undertaking, castings have already been used in many instances instead of forgings with complete success. To illustrate, let us mention tools, especially cutters, from free-cutting steel,[3] combined crankshafts,[4] guide blades of steam and gas turbines, etc. In recent years a method has been evolved, the aim of which is directly to use for the production of pressings and rolled products, pieces cast into water-cooled moulds in accordance with the method of Holub.[5]

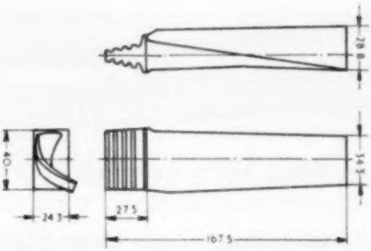
There are many properties which differentiate steels or special alloys of the same chemical composition in the cast or the forged state. These change often in relation to the type of steel or structure. Certain of the basic properties, which distinguish the character of cast from mechanically-worked structural components, may be considered to be generally valid. These can be summarized as follows:

A mechanically-worked structure is always fibrous, a cast one is granular without fibres. Mechanically-worked materials always have differing mechanical properties in the longitudinal and transverse direction in relation to the orientation to the direction of the fibres, while cast structures have the same values in all directions.

As a general rule, values of the mechanically-worked materials, namely those which characterize the plastic properties, are higher in the longitudinal direction of the fibres than the values for the cast materials, where the chemical composition remains the same.

In certain instances, however, the values for

2 *Final character of the fibres of a crankshaft, press forged from a normal billet (see* **1a**)



4 *Main dimensions of runner blade A*

5 *Shape and character of runner blade A after machining*

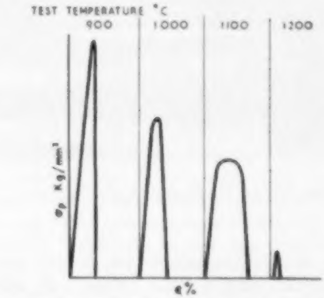
the mechanically-worked material in the transverse direction are lower than the same values for the castings in any given direction.

By its nature, the cast structure is in general better equipped to withstand creep at higher temperatures, resists wear better, especially if a surface, fine-grain layer is preserved, and it generally has better heat resistance.

A mechanically-worked structure is more homogeneous, normally tougher, and has higher fatigue limit values under dynamic methods of loading. The internal damping capacity of mechanically-worked material is lower than that of cast.[6]

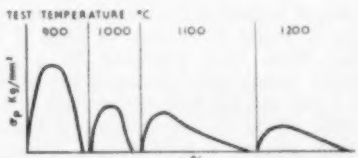
Pressings and forgings show less variation in their values from melt to melt than castings, and control of their quality is more reliable. In view of the fact that the production of castings presents an advantage in a saving in costs, a reduction in the consumption of charge materials, a shorter production cycle, a saving in machining and is theoretically unlimited in size and shape, the attempt to replace pressings by precision castings to the widest possible extent is completely justified. This trend is being investigated at the Lenin Works in Pilsen, and the results will be published elsewhere.

Sometimes, however, a cast structure does not fulfil all the conditions required from the operational point of view. For instance, precision castings of turbine runner blades, which are satisfactory in



σ_p Kg/mm²	15.3	10.6	7.7	5.0
δ %	2.4	5.2	16.8	14.8
ψ %	5.9	15.2	27.8	19.0

6 *Assessment of the forgeability of* VZČ 60 *alloy—the forgeability is very low*

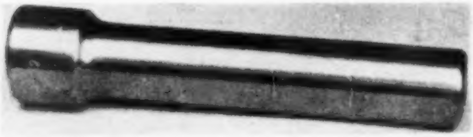


σ_p Kg/mm²	7.2	3.7	3.31	2.1
δ %	36.8	22.0	62.0	63.0
ψ %	90.4	27.8	96.3	99.6

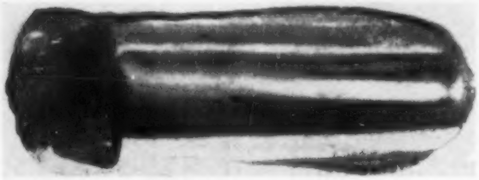
7 *Assessment of the forgeability of steel* ČSN 11600 — *the forgeability is excellent*

3 *Final character of a crankshaft, press forged from a billet cast into a water-cooled mould (see* **1b**)

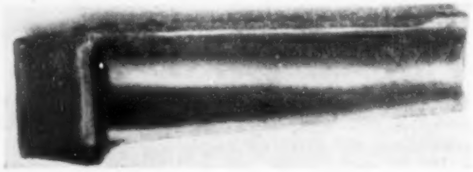
8 *Main dimensions of the as-cast shape for blade A*



9 *As-cast shape for blade A as made ready for press forging*



10a *Press forging for blade A before trimming*



10b *Press forging for blade A after trimming*

respect of all other properties, do not always reach the required fatigue-limit values. At other times, a material is developed which is most suitable for operation on the basis of its properties in the mechanically-worked state, but its forgeability is very limited, thus placing on plant and management in forge shops exceptional demands, and bringing to production considerable operational hazards. In such instances the use of castings is dangerous, and that of forgings is difficult. From the operational aspect it would sometimes be ideal if a turbine runner blade were produced by a technology, whereby certain parts possessed the advantages of both a cast and mechanically-worked structure. In the root, where the requirement of dynamic load-carrying capacity is predominant, a mechanically-worked structure would therefore be suitable. In the upper part, the fin, where above all creep at high temperatures and wear on the blade apply, a cast structure would on the other hand be most suitable.

These facts led to the development of mechanical working of structural parts from castings or as-cast shapes.

Basically we shall follow two possibilities:

(*a*) Normal production of drop-forgings from pieces cast into water-cooled moulds and not further mechanically worked. This method, intended above all for the working of structural steels, has been investigated by Holub, and will be published on completion. In fig. 1 for information the macrostructures of cast and rolled materials

11 *Macrostructure of precision cast blade A*

are compared, and in figs. 2 and 3 are compared sections of forgings of the same crankshafts pressed from cast and rolled billets. The specimens confirm the earlier presented comparison of the properties of the structures. The mechanical properties of the crankshafts pressed from cast billets were the same in all directions, and all of them higher than the values of the shafts obtained in the direction at right angles to the fibres (transverse values).

(*b*) Production of pressings from as-cast shapes in alloys with low forgeability.

Production of pressings from as-cast shapes

The principle of the production process is very simple. For the production of a drop forging use is made not of a sheared, mechanically worked bar, as is customary, but of a casting, the shape of which is so machined that the final nature of the structure shall be the best possible. The method follows best from examples. The aim, for instance, is to produce a gas turbine runner blade (figs. 4 and 5) from the special, creep-resistant alloy, VZÚ 60, of the following composition: 0·08–0·12% C, max. 0·30% Mn, max. 0·80% Si, 17·00–19·00 Cr, max. 15·00% Fe, 1·50–2·50% W, 1·80–2·50% Mo, 0·80–1·50% Ti, 0·30–0·80% Al, balance Ni.

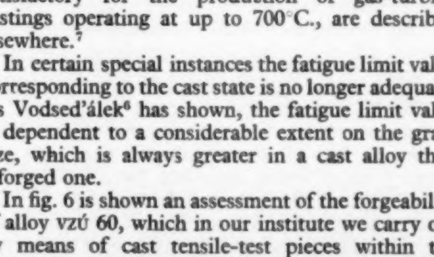
The properties of the alloy, which has proved satisfactory for the production of gas-turbine castings operating at up to 700°C., are described elsewhere.[7]

In certain special instances the fatigue limit value corresponding to the cast state is no longer adequate. As Vodsed'álek[6] has shown, the fatigue limit value is dependent to a considerable extent on the grain size, which is always greater in a cast alloy than a forged one.

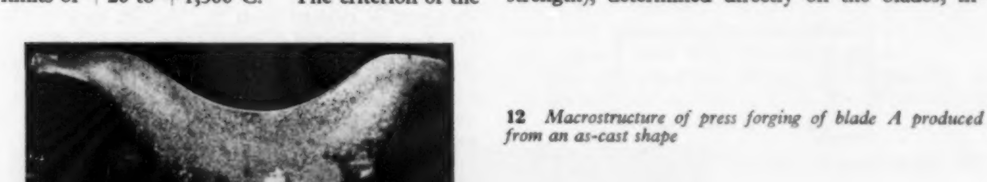
In fig. 6 is shown an assessment of the forgeability of alloy VZÚ 60, which in our institute we carry out by means of cast tensile-test pieces within the limits of +20 to +1,300°C. The criterion of the forgeability is the plot of the mechanical property values, especially of the elongation and reduction in area, and also the plot of the magnitude and nature of the resistances to deformation (work done in deformation). If we compare the forgeability defined in this way of alloy VZÚ 60 with the forgeability of carbon steel ČSN 11600 (fig. 7), the forging of which in technical practice does not create difficulty, we are able to observe that VZÚ 60 is an alloy which has only very limited forgeability. This was confirmed in practice, since forging of ingots of this steel into bars was practically impossible. In this instance it was not therefore feasible to attain a high fatigue limit by a change-over from the cast to the mechanically-worked state. A change to another alloy would lead in the given instance to an increase in the cost of production. For pressings, therefore, a casting was taken as the initial material; its shape is shown in figs. 8 and 9. By development of the casting of as-cast shapes for forging, carried out by Mašek,[9] the conclusion was reached that for their production it is possible to use all foundry methods known today. The casting was then press-forged by the normal method in a die with a tup and trimmed (fig. 10 *a* and *b*).

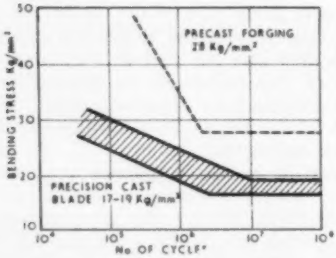
If we compare the structure of a precision-cast blade from the same alloy (fig. 11) with the structure of the press forging from the as-cast shape (fig. 12), we at once observe a considerable difference. As is evident from the macrostructure in fig. 11, the press forging from the cast shape forms an intermediate step between castings and forgings normal today, produced from forged bars. The structure of the root, where a high fatigue limit is required, has the character of mechanically-worked material, and on the spherical surface, which is subject to more considerable wear, the cast structure is in essence preserved.

As the course of the Wöhler fatigue plots shows, the value of the fatigue limit (plastic fatigue strength), determined directly on the blades, in-

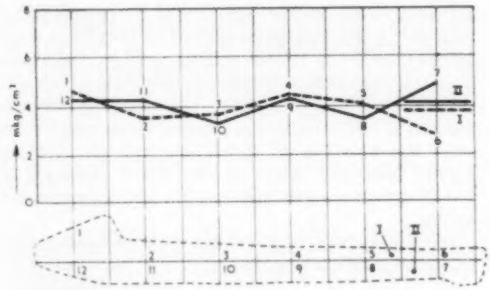


12 *Macrostructure of press forging of blade A produced from an as-cast shape*





13 *Comparison of the fatigue limit curves at +20°C., obtained from precision cast blades and blades press-forged from as-cast shapes.*
Top curve, press forging from as-cast shape; lower curve, precision cast blade



14 *Plot of the values obtained from micro-impact tests in the two structurally different areas (I, II)*

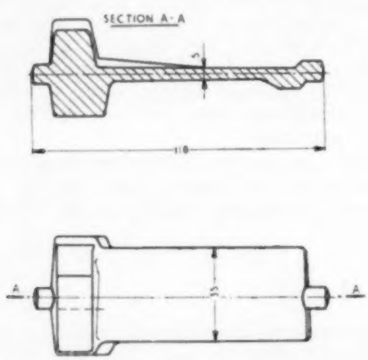
creased considerably by this method (fig. 13). At the same time, in agreement with table 1, a favourable influence was apparent on the mechanical property values, which were determined on test pieces machined directly from the cast or press forged blades. Fig. 14 records the results of notch micro-impact strength tests carried out over the whole longitudinal cross-section of the blade. Here also it was shown that the results obtained are very homogeneous. The described method makes it possible even in the special instance to use casting alloy VZÚ 60, which is advantageous from the raw material and price aspect, but has limited forgeability. At the same time a substantially higher fatigue limit was reached as opposed to the earlier castings produced from the same alloy.

TABLE 1 *Comparison of the mechanical tests carried out on blades at +20°C. Mechanical working produced substantial strengthening which also had an effect on the higher fatigue limit. The impact strength of the material also rose*

Value	Blade: Cast	Blade: Press-forged from as-cast shape
U.T.S., kg./mm.²	40·53	73·05
Yield strength, kg./mm.² ..	19·60	35·84
Elongation, %	14·3	31·45
Notch impact strength, kg.m./cm.²	9·43	10·93

The values are taken as the average of several tests.

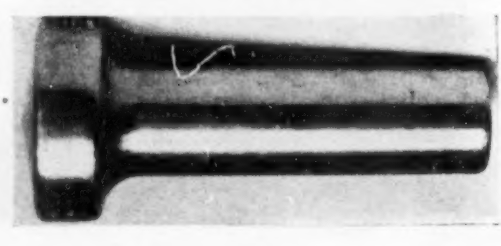
The second example is given to portray the technique used. For the shaping of the blade shown in fig. 15, as-cast shapes were cast, the rough form of which, including the riser, is shown in fig. 16, and the machined form in fig. 17. The blade was forged in a press from the rough casting by the normal method in two operations and trimmed (fig. 18). The character of the macrostructure is evident from fig. 19. In view of the fact that the degree of forging was low and another method was chosen for forging, the cast structure

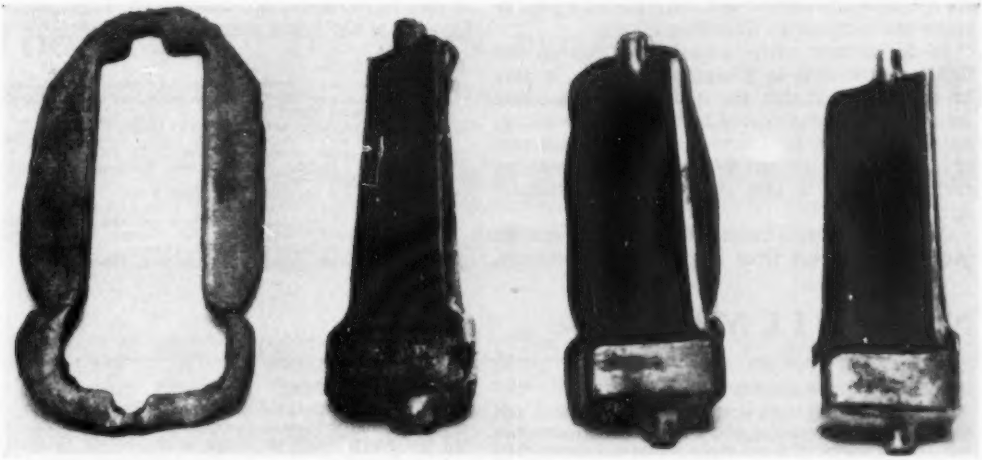


15 *Main dimensions of blade B*

16 *Form of the as-cast shape for blade B with riser after removal from the casting mould*

17 *Form of the as-cast shape for blade B in the final, rough-machined state before press forging*





18 *Press forging of blade B:* **a,** *discard after the first operation and trimming;* **b,** *trimmed piece;* **c,** *forging after the second operation;* **d,** *final trimmed forging*

was less destroyed than in the first instance. The choice of the method can be adapted to operational requirements.

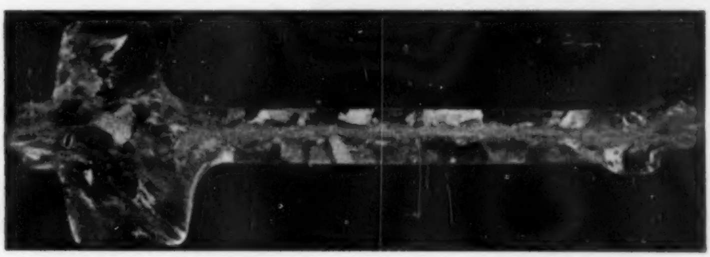
A third instance was also tried out, in which a precision casting was used as the initial material for the production of blades. In part of the root there was an addition for forging. In this instance it was possible to obtain a product in which the blade preserved the character of a casting and the root of a forging.

Conclusions

In technical practice use has hitherto been made of castings or forgings. In practice we have shown a third method which makes it possible to produce structural components, which lie between them in relation to their character and properties. At the same time, it is possible, in accordance with the selected method, to approximate to castings or to forgings, or to produce in one forging parts with a cast, and parts with a forged, structure. The aim of this paper is not to propagate the introduction of this method into current practice. It is also necessary to stress that the suggested method is a special one. It is always advantageous, if we can use a casting or forging, as is normal today. But the information can nevertheless be of value to our scientists in certain special instances, especially when a precision casting is completely unsuitable, or the available material has completely limited forgeability. We believe that the knowledge that it is impossible to obtain in a single structural component in various areas the advantages of a cast and forged structure will interest certain operatives, and that it will be further studied and developed.

By the methods described a large number of forgings have already been produced under normal production conditions with the use of ordinary metallurgical and forging equipment. Such forgings also already fulfil their function in service.

From the economic aspect it is necessary to choose accurate castings in all instances, where they



19 *Macrostructure of blade B, with a low, overall degree of forging*

are operationally suitable and can replace forgings or machined components from forged bars.

In an instance where accurate castings do not fulfil requirements in a certain direction, it may be recommended that the quality of an accurate casting should be improved by mechanical working, either in the whole structure or in a certain part of it, preserving the cast structure in the remaining part, in which a cast structure is functionally advantageous.

For materials with limited forgeability, where the production of bars from ingots creates difficulty, it may be recommended that as-cast shapes should be used as the initial material for forgings.

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(6) J. Vodsed'álek *et al.*, *Slévárenství*, 1960, **8** (4).
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NEW FILMS

Precision for the mighty

The application of heat is an essential factor in a vast number of manufacturing processes. This film examines some heavy engineering industries where it is shown that, despite the size of the projects, precision, careful processing and the maintenance of the highest standards are as necessary to the attainment of quality as in the finest of skills.

Processes included are gas carburizing, flame hardening and other heat treatments showing fully automatic methods which are employed in the production of Timken bearings and the massive Ruston-Bucyrus excavators, plate heating for fabricated pressure vessels, slab heating and associated processes in the manufacture of wide stainless-steel strip.

The film is intended for audiences with some technical knowledge and will interest meetings of engineering societies and other technical institutions. It will be of value to upper forms in secondary schools. It is a model of how this kind of film should be made—free from disturbing background music and facetious commentary, it really does instruct.

The Gas Council, 1 Grosvenor Place, London, S.W.1; 16-mm. sound and colour, 17 minutes' running time.

Carborundum films

The Carborundum Co. Ltd., Trafford Park, Manchester, makes several industrial films every year, and its film 'In the rough' won an award at the recent Industrial Screen Film Festival. The company's three latest films deal, respectively, with ceramic-tipped tools, refractory materials, and grinding wheels.

'The winning tip' deals with one of the most startling developments in modern mechanical engineering, the use of the ceramic-tipped cutting tool, for which considerable savings in time and costs are claimed.

Latest of the Carborundum control films, 'Heat in harness,' demonstrates how modern refractories serve the many industrial processes calling for precise control under high temperatures. From a modern research laboratory furnace to the baking of bread—from flame-out prevention devices in jet engines to the firing of fine-art pottery—the colour-camera passes over a wide and fascinating field. The finishing of racing car gears and astronomical mirrors to tolerances of less than 1 micro-inch is featured in 'To be precise.'

The three films are in 16-mm. sound and colour. Each runs for approximately 25 min.

Tool and die steels

The film opens with a series of operations showing the use of tool steels in a variety of applications—hot extrusion, hot stamping, pressure die casting, plastic injection moulding, compression moulding and cold forming and trimming of sheet metal.

Following this introduction, the film traces the sequence of manufacture of tool and die steels—from the melting of the steel, through the many hot working and testing operations, to the inspection of the finished product.

The concluding sequence shows how blocks of steel are transformed by the toolmaker into intricate dies and moulds.

There is some fine photography and some of the press forging sequences are well caught (see illustration).

Jessop-Saville Ltd., Brightside Works, Sheffield; 16 mm. sound and colour, 25 minutes' running time.

Toolmaking by spark erosion

P. J. C. GOUGH, B.A.(Hons. Oxon.), A.M.I.E.E.

Many aspects of electrodes for the spark erosion process are discussed, including materials, manufacture and positioning. The author is chief designer, Solar Weld Languepin Ltd., Burnley, Lancs.

THE SUBJECT of this article covers too wide a field to deal with all the aspects of application within the scope of a single treatment. Quite apart from the development work being undertaken by the author's company and by our French colleagues, the range of work with spark erosion covers almost every branch of engineering, including in particular the forging die, pressure die casting, plastic moulding and glass moulding industries.

The machine on which most of our more accurate work is done is the Seleromat 'B,' which has its servo-controlled electrode carrier mounted on a co-ordinate slide assembly enabling the electrodes to be positioned to an accuracy of $\pm 0 \cdot 0003$ in. over any station of the worktable, the size of which is 25×20 in.

The base of the machine is of welded steel construction and incorporates a supporting structure for the worktable, the housing for the 100-gal. dielectric-oil tank, and the associated tank raising and lowering mechanism. The tank completely surrounds the worktable and is raised and lowered electrically through push-buttons on the front of the machine; the tank raises with the dielectric until it submerses the workpiece and the electrode, and at the conclusion of the machining operation lowers with the dielectric so that workpiece and electrode are freely accessible. The necessity to fill and empty the tank as an integral part of each erosion operation is thus eliminated. The requisite level of dielectric fluid in the tank is maintained automatically by a pump housed at the rear of the machine base, and an electrical interlock prevents the transmission of power to the electrode unless the workpiece and electrode are immersed in the dielectric.

A centrifugal fan driven by its own electric motor is also housed at the rear of the machine base. The inlet tract to the fan is flexible trunking which enables the extractor inlet to be placed adjacent to the electrode to capture the erosion fumes. The fan exhausts through the rear wall of the machine base into suitable ducting to carry the fumes away to atmosphere.

The worktable, which will accommodate workpieces weighing up to 1 ton, has two T-slots to take clamping bolts, but these are required only for steadying the workpiece against accidental movement because no mechanical loads are imposed by the erosion operation.

The servo-controlled electrode carrier, which has a total vertical movement of 4 in., is controlled by a d.c. split-field motor working through a reduction gear-box. The signal to the motor is obtained from a d.c. amplifier, the input of which is obtained by comparing the voltage drop across the spark-gap with a reference voltage.

The spark generator which is used with the Seleromat 'B' machine is capable of erosion rates of 2,000 mm.^{3} and above. Power is derived from a single-phase alternator, the output frequency of which is $2 \cdot 5$ kc./s. The output voltage is tuned to a predetermined value and coupled across a full-wave rectifier bridge. The output from the bridge is fed direct to a condenser bank which, in turn, discharges across the gap between electrode and workpiece. By means of a heavy-duty switch it is possible to select one of four different outputs which allow erosion rates from 2,000 mm.^{3} down to 2 mm.^{3} to be used. Erosion rates lower than this, depending on the suitability of the electrodes, can be obtained if very fine surface finishes are required.

Electrode materials and manufacture

The choice of electrode material for any particular erosion task is one for which almost everyone who is working with spark erosion today would appear to have their own technique of solution. In the event, the choice must necessarily depend on the work which is to be undertaken, and economy is likely most frequently to be the first consideration. Copper, although not the cheapest of electrode materials, usually produces the best results and, therefore, finishing electrodes are almost always made from this material.

Of the various ways in which electrodes may be constructed, milling from bar or from rough castings

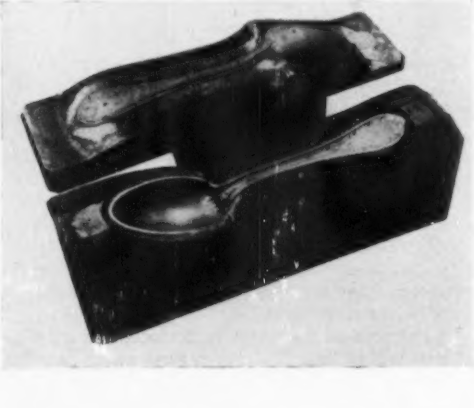
is probably the easiest, providing that the electrode shape is of a kind that allows milling in the conventional manner rather than copy-milling. My company has found that it is not always easy to obtain cheap, good-quality castings in copper, and we have therefore often used phosphor-bronze which is easier to cast and gives very good results.

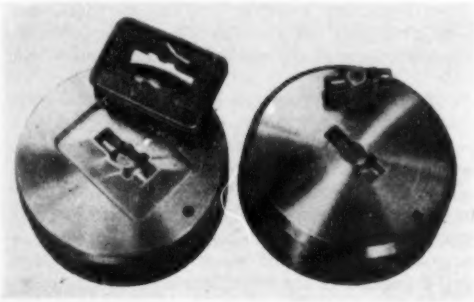
It is our experience that if copy-milling or complex milling operations are necessary, it is often worth while attempting to form the cavity by making up a number of discrete electrodes which together form the entire cavity. Where copy-millers are available, however, it is frequently quite easy to construct a model of the cavity required, which can be used as the copy-form for producing a number of similar electrodes. It is recommended that the model for a copy-miller should be made in copper, or the electrode material, for not only is it easier to produce the male form of a cavity, but the form so produced can be used as a further model from which plaster moulds can be made and into which copper can be sprayed. Sprayed electrodes are cheaper than those machined from the solid, and consequently it is more economic to use these to produce most of the cavity, leaving the original model for use in the final finishing operation.

For deep, complicated cavities a minimum of three to four electrodes are required. The sizes of these have to be adjusted by acid etching to suit the various erosion rates which are employed in forming the cavity. It is, of course, far better to spend more time in the region of high erosion rates, thus keeping to a minimum the amount of time spent producing the final finish. Wherever possible it is more expedient to remove as much metal as possible by conventional techniques before applying spark erosion, but naturally this is not the case when hardened steels are being used. In these instances it is usually better to 'rough-out' the cavity first, harden, and then carry out the spark erosion operations. This eliminates the possibility of distortion and cracking which sometimes occur when a finished die is hardened.

When the dimensional accuracy requirement is less than $\pm 0{\cdot}001$ in. the maximum economy may be effected by the entire use of sprayed electrodes. If a steel mould is already in existence, spraying presents no problems, but if one is starting with a new die, then one is faced with the problem of making a model of the cavity in wood, Perspex or metal, and from this model forming the plaster moulds into which the copper is sprayed. Whether produced from a plaster mould or a steel mould, sprayed copper electrodes lend themselves very easily to the insertion of copper or brass pipes which can be used for dielectric fluid injection. Our experience is that sprayed copper electrodes work very well, and the loss of electrode by erosion is no worse than that which applies with copper bar. Our French colleagues have perfected the art of producing plaster moulds, and they are now in a position where they can produce from a single

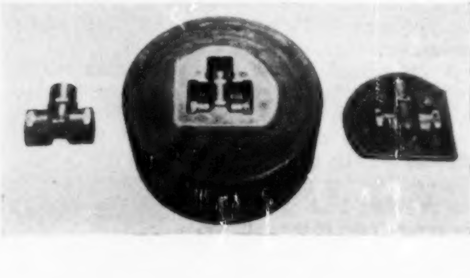
1 *Cold-stamping die for cutlery. By erosion-machining the die production time is* 20 *h.*: *by conventional methods die-making takes* 50 *h.*

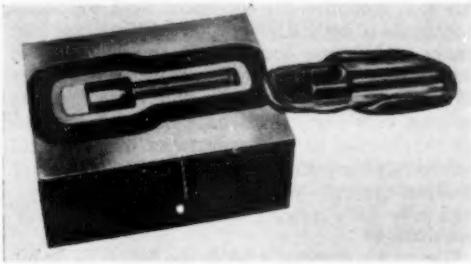




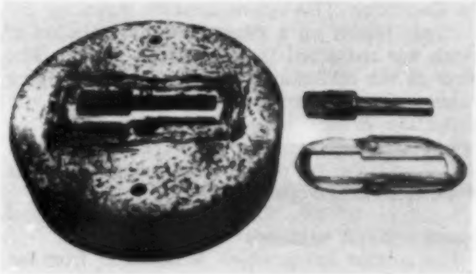
2 ABOVE *Hot brass stamping die set together with electrodes for the cavity and the flash gate. Production time for an eroded die-set is* 9 *h.*: *for a normally made set it is* 20 *h.*

3 BELOW *Brass stamping die with component on left and electrode on right. This die was spark eroded in* 4½ *h. by comparison with the normal production time of* 11 *h.*





4 *Forging die for lock spindle together with typical forged electrode. The production time for eroding this die is 1 h.: by normal means the production time is 4½ h.*



5 *Spark-eroded clipping tool for removing the flash from lock spindles forged with the eroded die shown in* 4.

model a number of plaster moulds, the dimensional accuracy and surface finish of which are as good as those of the original model.

Copper is sprayed into these moulds cyclically in batches; that is to say, seven or eight moulds are taken together and sprayed in cyclic sequence. To ensure that the temperature of the copper is kept low, a small amount is sprayed into each mould in turn so that by the time the cycle is complete the copper has cooled in readiness for the next cycle of spraying. The process is repeated until a sufficient thickness of copper has been built up in each mould —usually an overall thickness of 0·1 in. is enough.

Perhaps the most significant work yet undertaken by the author's company, which illustrates the way in which a large number of simple shape electrodes can be used, is the construction of a gravity die mould which was produced for one of our associated companies for the main body of a hand tool. From their experience it is now obvious that dies made in Nimonic will last as much as three times as long as dies made in conventional tool steel, and it was therefore decided in this particular case to use Nimonic 80. It is significant to note here that this die was produced entirely by spark erosion, and over 60 electrodes were used in the construction of both halves. The total time taken to make these 60 electrodes (of comparatively easy shape) was 300 h., this including the time taken to produce the jigs and fixtures to hold the electrodes. The total time taken to produce this die by conventional techniques has been established at 680 h., whereas the time taken to produce a single die-set by spark erosion is 470 h.

In the drop-forging field, of course, the need for repetitive dies is very much greater than applies with die casting or with plastic moulding, and the question of electrodes is a relatively simple one. Existing steel dies can be used as patterns for sprayed electrodes, or electrodes can be forged and, providing care is taken during the forging of the electrodes, then good cavities can be produced.

Electrode materials vary for different machines; in some cases aluminium is quite a good material and results are such that performances can be obtained which are equally as good as with copper. In other cases cast iron can be used with very good effect. Copper-tungsten is reputed to produce the best effect when especially high precision is required, and it possesses the advantage of having a very low erosion rate. The price of copper-tungsten is about eight times that of copper.

Electrode application

The way in which electrodes are located and used is as important as their manufacture, and a great deal of success and, in particular, speed of operation depends on this. With most cavities, and especially re-entrant cavities, dielectric injection is essential. This must be used in such a way that clean dielectric fluid is injected into those regions of the spark gap where the products of erosion can accumulate. It is also worth noting (and this is not so well known) that it is occasionally of use to provide in the electrode a somewhat larger hole which will allow the escape of exhaust gases trapped in the spark gap.

When dielectric injection and exhaust holes are used, a number of ' pips ' will be left in the cavity after the first electrode has been used. These ' pips ' may be removed by the next electrode by re-positioning the injection and exhaust holes. When a number of electrodes are used, this process can be repeated until the final stage is reached when a ' pip ' of only 0·001 in. or 0·002 in. will remain. These final ' pips ' can be removed by grinding or, if they are in positions where grinding is not possible, small electrodes can be made which can be used to erode the ' pips ' to the final surface of the die.

A further method whereby the products of erosion may be assisted from the gap is by vibrating

the electrode. This can be done by mounting the electrode carrier on a vibrator, the oscillations of which are restrained to the vertical plane. The effect of the oscillation is to produce a pumping action which, in turn, produces compressions and rarefactions in the spark gap; the resulting agitation pumps away the eroded debris, and is usually quite sufficient to remove the heaviest erosion products from the spark gap.

Spark-eroded surfaces

The surface finish which is obtained from an electrode depends entirely upon the surface finish of the electrode itself, and our experience shows that, if sufficient care is taken in preparing the electrode surface, finishes of the order of 0·5 microns can be obtained without difficulty.

We have conducted some tests on the surface structure produced by our own spark erosion machines, and our findings confirm previous experiments which establish that a spark-eroded surface consists basically of four layers. Micro-hardness tests reveal the disparate variation from the parent metal to the outer skin or surface. It is questionable whether the hard surface produced by spark erosion is a detriment since most work-pieces are produced with the die in the hardened state and, therefore, any additional work which has to be done is normally done by grinding, and the change in hardness between the surface structure and the parent metal would consequently be very difficult to establish. French experience supports our own view that this surface hardness is in no way detrimental to the performance of a die, and in drop-forging work the extra hardness is possibly an advantage.

Conclusions

The author personally holds the belief, as do his colleagues in France and at the home company, that spark erosion is a process that will become a natural part of toolroom procedure. We also believe that there is much development still to be done in the production of dies and tools and, in this respect, we hope to be able to produce a machine which will, in fact, take its place alongside the tape-controlled milling machine.

The stage is foreseen where non-consumable electrodes will allow a programme for the movement of the electrode over a surface in order to produce a cavity which is as complex as any which can be produced today, but which will not require the complexity of electrodes which, in certain difficult applications, is unavoidable today.

Effect of structural changes, etc.

LUBOMIR CIZEK, DR. JAROSLAV JEZEK AND JOSEF VOBORIL

Concluded from page 442 *of the article which appeared last month*

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concluded from page 474

diameter of the billet is more than 160 times its thickness. The article describes the production of such covers from stainless and acid-resisting steels, titanium, etc., with ratios of the diameter to thickness exceeding 800–1,000. For the stamping operation a tack-welded, composite billet is used consisting of the billet to produce the finished component, sandwiched between two billets of carbon steel, whose ratio does not exceed 160. After stamping, the three stampings from the composite billet are parted.

A die for punching apertures. A. G. KOKIN. Pp. 43–44. Production of meat mincer cutters previously required three operations: (1) blanking of a billet of 59 mm. dia., 6 mm. thick; (2) punching of an 8-mm.-dia. aperture and of a 4-mm.-wide slot; (3) drilling of 48 holes of 4 mm. dia. The author describes his own die for simultaneous punching of the aperture, slot and holes in a single operation.

The wear resistance of caprone sleeves used on hydraulic presses. N. V. DREVAL' and V. I. ISEKOV. Pp. 44–45. Leather sleeves may advantageously be replaced by sleeves of caprone + 25% $BaSO_4$. Comparative lives are 10–12 days and 2 months respectively.

The cold extrusion of steel

R. A. P. MORGAN, O.B.E., M.I.Mech.E.

The relatively new field of cold extrusion of steel is surveyed in this article and its techniques discussed with many practical examples. Mr. Morgan is Engineering Director of the War Department. Superintendent, R. O. F. Birtley*

concluded from last month

Analysis of the degree of strain and hardening of an extruded cylinder

A COMPONENT was made by single impact from a cylindrical billet to the proportions and hardness figures shown in fig. 29.

It is interesting to note the pattern of hardness figures which follows the strain pattern on the material, which is illustrated clearly by analogy with the four stages of extrusion of a laminated plasticine billet (fig. 30).

It is also interesting to note the degree of elongation which each particular part of the surface receives during extrusion. To determine this, a grid was engraved on the cut face of a longitudinally sectioned billet which was then extruded. It was not practicable to photograph the deformed grid, but fig. 31 illustrates the results obtained.

On the left of fig. 31 is a diagrammatic representation of the billet. The vertical markings *A–J* are shown in full and the resultant pattern after extrusion is on the right. For clarity, the horizontal markings shown (*S–Z*) on the billet (left) are the original boundaries of the various degrees of surface elongation found after extrusion (right).

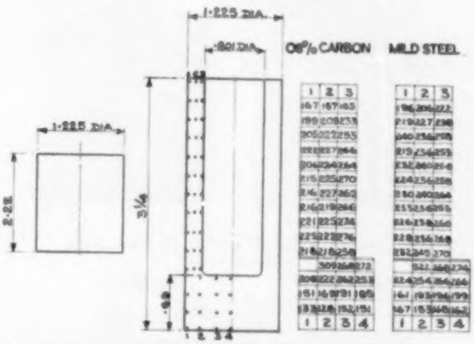
*Article based by the author on his lecture given at the Wolverhampton and Staffordshire College of Technology last March at a two-day symposium on 'Cold flow forming.' The article, published in three parts, is concluded in this issue of METAL TREATMENT.

For this extrusion the material used has been 0·08% carbon steel and commercial mild steel (STA/5.V3), typical analysis being:

	C %	Mn %	Si %	S %	P %
Low-carbon steel ..	0·08	0·12	0·07	0·020	0·016
Mild steel ..	0·21	0·42	0·20	0·041	0·036

The strength characteristics of these steels are shown by the mechanical test results, before and after extrusion, in table 4.

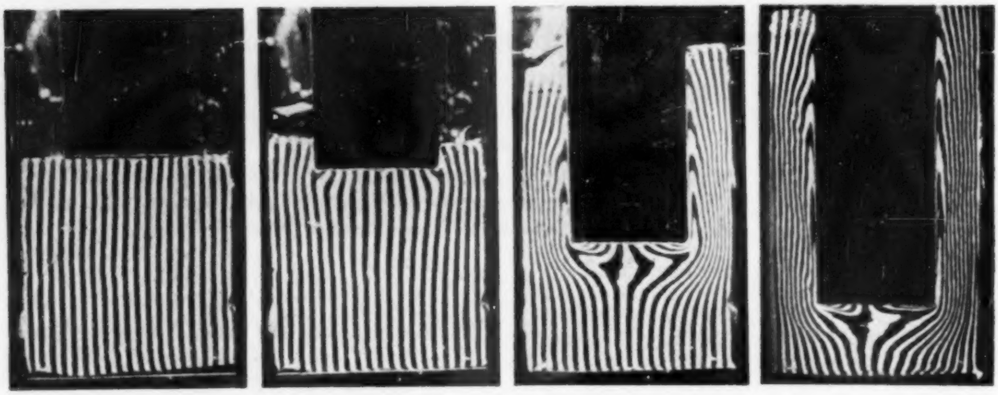
The tests in the extruded condition were from



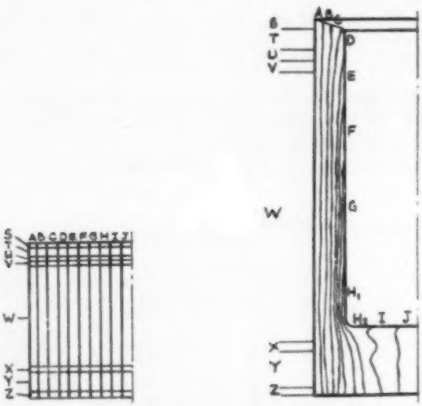
29 *Proportions and hardness figures of component made by single impact from cylindrical billet*

TABLE 4 *Strength characteristics of two steels, before and after extrusion*

	Y.S. tons/sq. in.	U.T.S. tons/sq. in.	Elong. % $4\sqrt{A}$	R. of A. %	Izod ft./lb.	Hardness V.P.N.
Low-carbon steel:						
Annealed	14·1	24·3	45	65	80	108
Extruded	48·3	49·3	24	46	28	—
Extruded	50·0	50·8	16	46	45	—
Mild steel:						
Annealed	15·2	25·2	40·5	68	78	122
Extruded	51·8	52·7	23	45	29	—
Extruded	52·8	53·0	23	44	48	—



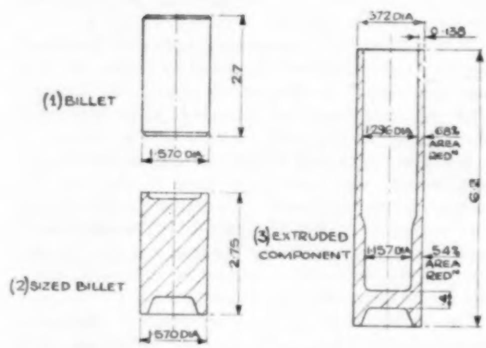
30 *Four stages of extrusion of a laminated plasticine billet*



SURFACE EXTENSIONS AFTER EXTRUSION (PERCENTAGES)

INTERIOR		EXTERIOR	
A	0	S	0
B	0	T	120
C	0	U	144
D	220	V	160
E	520	W	192
F	640	X	128
G	1060	Y	120
H1	1720	Z	0
H2	230		
I	230		
J	230		

31 *Degree of elongation of different parts of surface after extrusion*



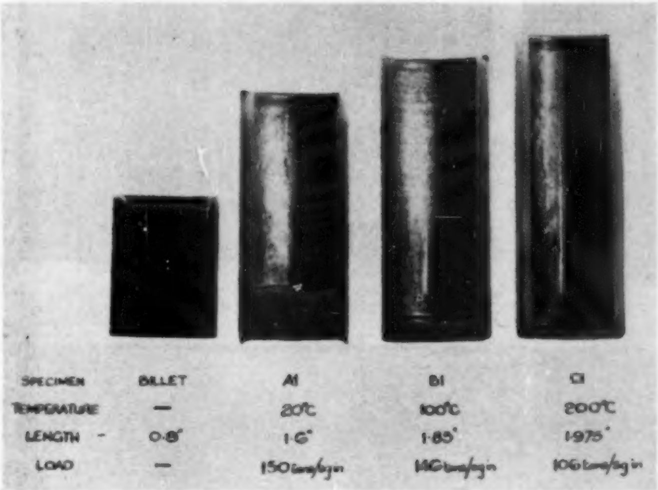
32 *Single-shot extrusion of a shell body*

miniature test pieces cut from the walls of the tubes, the hardness of which shows considerable variation, as has already been shown. This factor is probably responsible for the variation in elongation and particularly in impact values, where it has been shown that the result can vary with the position of the notch in relation to the more heavily worked inner surface of the tube.

Punch loading obtained in practice

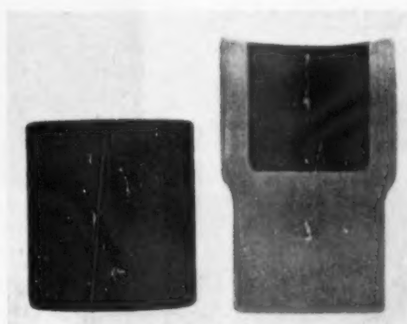
Some important figures on punch loading are recorded in the following notes relating to the single shot extrusion of a shell body shown in fig. 32. This work was carried out on two steels, namely:

	C %	Mn %	Si %	S %	P %	Ni %	Cr %	Cu %
Rimming steel	Core 0·03 Rim 0·09	0·16	0·02	0·055	0·020	0·09	0·04	0·05
Killed steel	0·08	0·12	0·07	0·02	0·016	0·20	0·15	0·33

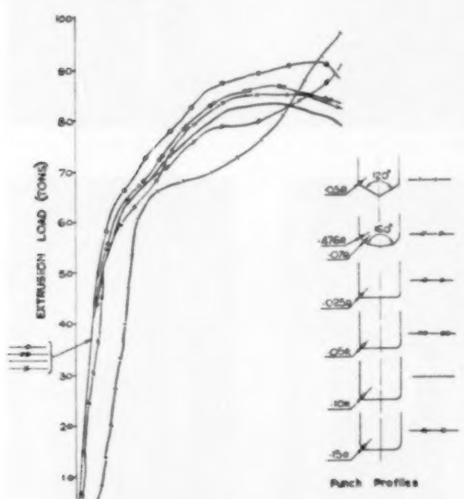


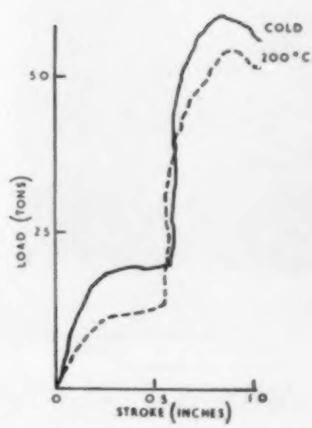
34 LEFT *Influence of temperature on the extrusion of steel*

35 BELOW *Combined forward and backward extrusion*



33 BELOW *Results of trials carried out to assess the best punch nose profile*





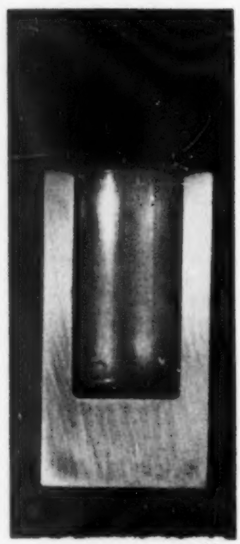
36 RIGHT *Curves taken from production trials of component shown in* **35**

37 ABOVE *Cold upsetting of mild-steel billets, 1½ in. sq. × 1¼ in. thick to 4 in. × 3/16 in. thick*
Load approx. 1,500 tons

38 TOP RIGHT *Billet in mild steel*
Billet 1⅜ in. dia. × 0·72 in. in mild steel, formed to shape increasing the face area from 1·49 sq. in. to 3·14 sq. in.
Dia. across horns = 2⅜ in.
Thickness = 0·34 in.
Load = 380 tons approx.

39 RIGHT *Cold upsetting of mild-steel billets, 2 × 0·6 in. to 4·1 × 5/16 in.*
Load approx. 1,500 tons

40 BELOW *Flange forming and extrusion from a plain billet*
I. dia. = 0·88 in. O. dia. body = 1·58 in. O. dia. flange = 3·15 in.
Length = 3·2 in. Thickness of flange = 0·35 in.
× Section area body = 0·61 sq. in. % Reduction area = 39%.
Load = Form 300 tons approx. Pierce 70 tons approx.



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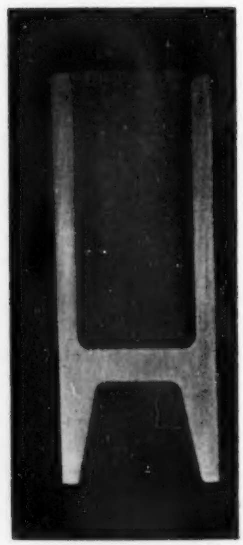


42

41 RIGHT *Projectile component — backward extrusion (steel)*
I. dia. = 0·8 in. O. dia. = 1·225 in. Length = 2·2 in.
× Section area of billet = 1·18 sq. in. % Reduction = 43%
Extrusion load = 68 tons = 136 tons/sq. in.

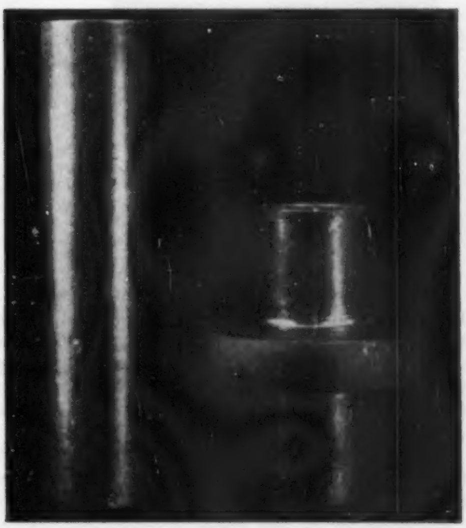
42 RIGHT *I. dia. = 0·85 in. O. dia. = 1·18 in. Length = 3 in.*
× Section area of billet = 1·09 sq. in. % Reducton = 55%.
Extrusion load = 77 tons approx. = 136 tons/sq. in.

43 *Steel energizer container—backward extrusion*
I. dia. = 1·5 in. O. dia. = 1·9 in. Length = 2·2 in.
× Section area = 1·07 sq. in. % Reduction = 62%
Extrusion load = 260 tons approx. = 150 tons/sq. in.

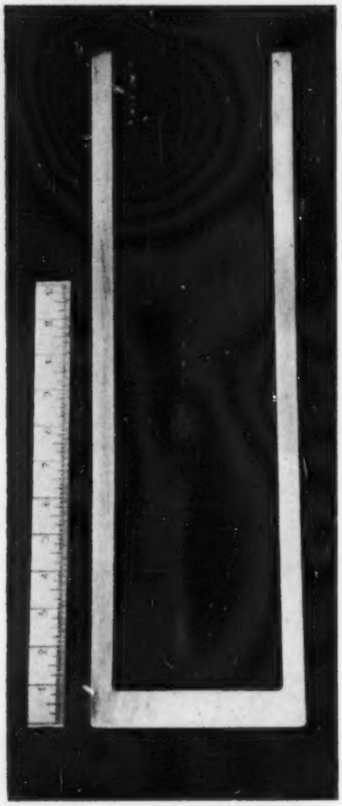
44 *Combined backward and forward extrusion from round billet*
I. dia. = 2·4 in. O. dia. = 3·08 in. Length = 6 in.
Thickness through mid-section = 0·55 in.
× Section area = 4·5 sq. in. % Reduction area = 60%
Load = 660 tons approx.

45 *Squeezing a square section bar into a round billet (mild steel)*
Billet dia. = 3·1 in. Thickness = 2 in.
× Section area of billet = 7·55 sq. in.

46 *Extrusion of formed billet*
I. dia. = 2·1 in. O. dia. = 3·1 in. Length = 3·3 in.
× Section area of billet = 7·55 sq. in. % Reduction area = 46%
Load = 450 tons approx. = 130 tons/sq. in.

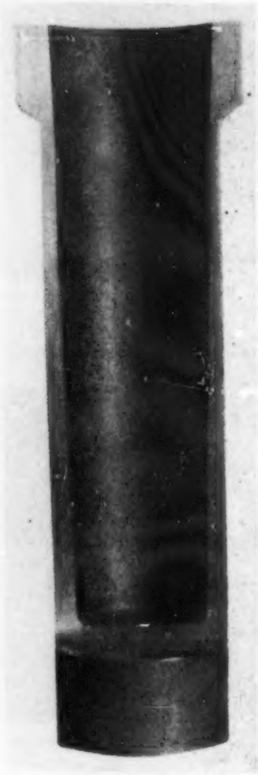


47 *Swelling mid-section of 1-in.-dia. bar (mild steel)*
Shows billet 1 in. dia. × 4½ in. long and finished pressing.
Mid-section increased from 1 in. dia. to 2½ in. dia., i.e. increase in cross-section area of 350%



48 *Hydraulic buffer—backward extrusion (steel)*
I. dia. = 4·45 *in.* *O. dia.* = 5·7 *in.*
Length = 18½ *in.*
× *Section area of billet* = 12·6 *sq. in.*
% *Reduction* = 69%. *Load* = 2,000 *tons*

49 40 *L.70 shell—backward extrusion (steel)*
I. dia. = 1·24 *in.* *O. dia.* = 1·565 *in.* *Length* = 6 *in.*
× *Section area* = 0·7 *sq. in.*
% *Reduction* = 68%
Extrusion load = 200 *tons*

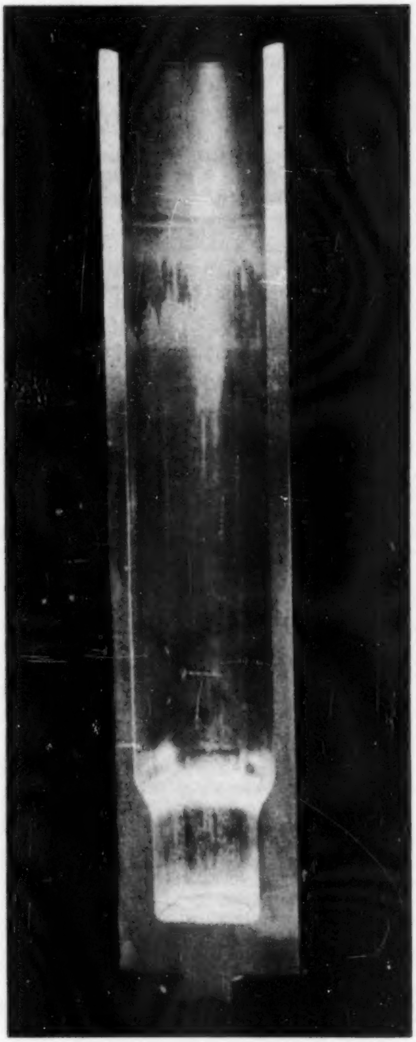


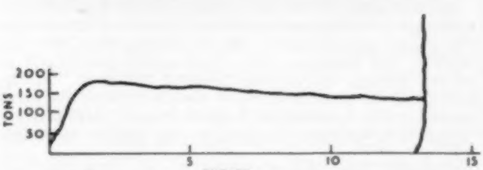
50 40 *L.70 shell—forward extrusion (multi-operation)*
Mean internal dia. = 1·285 *in.*
O. dia. = 1·56 *in.* *Length* = 6¼ *in.*
Mean × *section area* = 0·615 *sq. in.*
% *Reduction* = 33%
Extrusion load = 200 *tons*

All billets were sub-critically annealed to a hardness of about 120 V.P.N. and after dimpling were re-annealed and single shot extruded. Various tool steels were used, all of which failed by swelling, bending or fracture, and no steel was successful for continuous operation. Punch loadings were as shown in the table on the right.

It will be seen that the strength requirement is far higher than could normally be expected from a tool steel and, in point of fact, 120 tons/sq. in. is considered to be the absolute maximum design load for tools of this nature with a preference, for production purposes, of 100 tons/sq. in. max. It was observed that the tools which bent or became swollen did so at about 180–200 tons. Above 200 tons (press loading) the tools fractured near the nose.

	Total load tons	Tons/sq. in.	
		Minor punch dia.	Major punch dia.
Initial extrusion on small dia. of punch	160–170	152–161	120–128
Extrusion on to major dia...	200–210	188–197	151–158





51 *Rocket component—4½% Cu aluminium alloy HE* 15 *—backward extrusion*
I. dia. = 1·734 in. O. dia. = 2·312 in. Length = 12½ in.
× Section area = 1·88 sq. in. % Reduction = 55%
Extrusion load = 180 tons

Punch nose profile and the effect upon extrusion load

Various trials were carried out in order to assess the best punch nose profile. These trials consisted of: (i) flat-nosed punches with varying radii at the junction between the flat nose and the side; (ii) punches with coned nose form.

The results of these trials are illustrated in fig. 33, from which the following conclusions are clear.

A conical shape to the nose of the punch reduces the punch loading required until such time as a breakdown in the phosphate and lubrication causes a steeply increasing load requirement.

Flat-nosed punches serve to maintain the phosphate and lubrication at the base of the cavity and give a regular and increasing load requirement in accordance with the depth of penetration until nearly maximum penetration is achieved, after which the load requirement tends to fall.

The degree of radius at the junction between the flat nose and the side is important in reducing punch loading.

From the graphs it will be seen that maximum punch loading varied from 137–157 tons/sq. in., and hence a reduction of nearly 13% can be achieved with the best radius.

Warm temperature effects upon the extrusion of steel

Certain work has been done in this regard in an endeavour to reduce the load on the extrusion punch. Trials were carried out in the laboratory using a testing machine which extruded at the rate of 6 in./min. punch speed. The results were as in table 5.

TABLE 5 *Temperature effects on extrusion*

Temperature	Test sample	Peak load on punch tons/sq. in.	% decrease in load from D 1
Ambient	A 1 A 2	150* 154*	— —
100°C.	B 1 B 2	146 139	16 20
200°C.	C 1 C 2	106 112	39 36
Ambient	D 1	175†	—

* Test stopped before peak load on reaching safety limit of tools.

† Peak load but bolster fractured immediately afterwards.

Higher temperatures than 200°C. were not successful, owing to the fact that the lubrication tended to char.

It was clear from the analysis of the hardness figures of the resulting components that the

extrusion in each case was following a somewhat different pattern. The mean hardness figures of mid-wall positions were as follows:

	V.P.N.
Billets prior to extrusion	111
Components extruded at ambient temp.	208
Component extruded at 100°C. ..	214
Component extruded at 200°C. ..	220

The components are illustrated in fig. 34. Unfortunately, *D*1 was destroyed on being extracted because of damage caused by the broken bolster, but the base thickness was in the same order as that of *B*1.

However, in specimens *B*, *C* and *D* the base thickness is not significant, since deformation is proceeding at below the peak load, and the final base thickness depends very much on the operator in the absence of positive stops in the rig.

Sample *C*1 shows a base thickness in the order of about half the wall thickness, and a microscopical examination fails to reveal anything other than a suggestion of incipient shear on the bottom radius. This is contrary to normal results where a shear crack forms on the base/wall junction at a base thickness of 1*T* and thereafter there is a very sharply rising load requirement to bring about further base reduction. It will be very interesting to continue these trials to ascertain the role of the temperature in this respect.

Following the laboratory trial, a further trial was carried out on factory plant using an existing set-up which was currently in production. In this, the component was a combined forward and backward extrusion as in fig. 35. Curves were taken using an automatic indicator which yielded the result shown in fig. 36. The first extrusion peak is caused by the forward extrusion of the billet into a reduced die annulus. The second extrusion peak is caused by the subsequent backward extrusion. A substantial difference in punch loading is indicated by the curves and also by the figures in table 6.

TABLE 6 *Effects of temperature on tool loading*

Temperature	Actual tool loading (tons)			
	1st peak	% decrease from cold	2nd peak	% decrease from cold
Ambient	17·4 18·6	— —	57·0 57·0	— —
150°C.	12·4 13·6	31 25	51·0 51·0	10 10
200°C.	12·4 12·4	31 31	52·0 52·6	9 8
250°C.	12·4 14·2	31 21	53·5 54·5	6 4

These trials seem to establish a greatest reduction in punch loading at 150°C.

At this stage it is not possible to say whether this reduction is due to more efficient lubrication performance or to physical characteristics in the steel, but experiments with and without certain lubricant additives seem to indicate that it is a combination of both. The physical characteristic change would be the strain-ageing phenomena, of which very little data appears to be available at these temperatures associated with the speed of working. This development is as yet in its infancy, but the facts obtained so far have been recorded in this paper for information.

Flash-annealing furnace at Birmetals Ltd.

A NEW STRIP MILL for rolling of aluminium alloys has been installed at the Quinton, Woodgate Works of Birmetals Ltd. This Sendzimir mill, the first of its type to be used for this purpose in Europe, rolls the alloy in coil form at 1,600 ft. a minute.

Working in conjunction with this new Birmetals development is a flash-annealing furnace which will take sheets up to 8 ft. wide, or two 4-ft. wide sheets, side by side. This latter equipment was designed, manufactured and installed by G.W.B. Furnaces Ltd., of Dudley, Worcs. The furnace has four heating zones totalling 600 kW.

During the early stages of the furnace's commissioning, extensive tests were carried out to ensure the maximum uniformity of material heating across the width. Eight patent centrifugal two-speed fan units were provided mounted on one side of the furnace chamber, and these, working with the requisite system of air-directing baffles, provide the charge with an evenly distributed flow of hot air.

The heating elements were manufactured from highest quality 80/20 nickel-chromium heavy strip, in sinuous form, supported within the upper portion of the furnace interior and separated from the charge space by heat-resisting steel baffle plates.

Effective dimensions of the furnace are (ft.): Loading length, 6; heating chamber, 40; cooling chamber, 70; unloading table, 6; width, 8½.

The heating zones, together with variable speed fans, ensure a high degree of temperature uniformity over the width of the conveyor, while a degree of super-heat can be given to the charge on its entry into the first zone of the furnace. Temperature range is 150–550°C.

The furnace was designed to give a nominal throughput of 2 tons per hour, although figures far in excess of this have, in fact, been achieved.

At the loading end of the furnace a series of rectangular rubberized balata ropes are provided so as to ensure that the sheets are not marked during loading on to the conveyor. The sheets are then automatically transferred on to the furnace and cooling chamber conveyor. At the exit from the cooling chamber the strips are once again passed on to a rubberized balata band conveyor from which they are taken by hand by the furnace operators.

Optoshield Ltd., manufacturers of eye protection and other safety products, are transferring all their production and development departments to more spacious accommodation at Watford. The Sales Department and head office remain at 146 Clerkenwell Road, London, E.C.1, and orders should continue to be sent there.

Method to reveal austenitic grain size in hardenable steels

M. KALDOR and J. A. VERO

A method is described which reveals the austenite grain size of hardenable steels by means of the relief formed during martensitic transformation. Two polished samples fitted together are heated in an inert atmosphere and quenched. On the polished surface the grain size of austenite is now visible without any further preparation or etching. The method is useful for ball-bearing steel. If the samples are etched, some details of the transformation become visible*

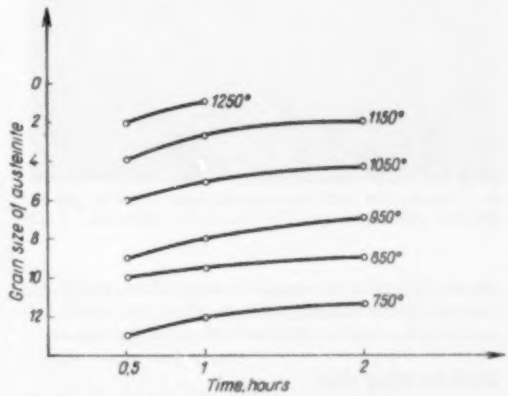
THERE ARE SEVERAL methods to measure, or more precisely to reveal, austenitic grain size of steels.[1] Some of these can be used only for steels within rather narrow limits of composition, such as measurements based on the network of ferrite or cementite. Other methods are difficult to carry out, such as the preparation of gradient quenched samples or the production of a ferrite network by stepped quenching. Further methods, such as McQuaid-Ehn's carburizing test[2] or quenching a previously polished sample after austenitizing in hydrogen have also certain limitations in selecting the conditions of austenitizing.

In fact, there are certain types of steel for which hardly any conveniently applicable methods can be found. An example is a steel containing about 1% carbon and 1·5% chromium, generally used as ball-bearing material, the grain size of which can be determined only by comparing the fracture of a quenched sample with a standard set of fractures representing the ASTM grain size grades.[4] Another steel for which no reliable method is known is the low-carbon case hardening or weldable steels containing less than 0·2% carbon, especially if fine grained.[3]

Knowledge of the austenitic grain size of these steels is often desirable when specifying them for use. Therefore, the relatively simple method accidentally found during another research work on ball-bearing steel should be described. The method has successfully been used with the two above-mentioned kinds of steel, but doubtlessly it will prove applicable to all grades of steel which become martensitic on proper cooling.

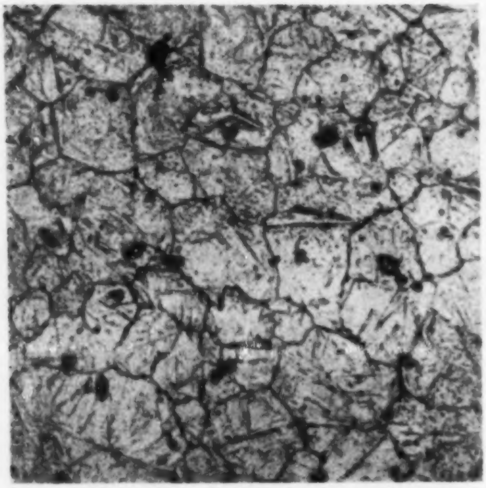
Our method is the following. Two discs of steel, having a diameter of about 12 mm. and a thickness of 3 mm. are ground and polished on one circular side and assembled, the two polished surfaces being in good contact. The two discs are fastened to each other in this position by means of wire; notches on the circumference or two boreholes going through both discs make wiring easier and more secure. The circumference of the double disc is then smeared with some alumina made up with water glass and dried at 80°C.

The pair of discs, suspended on a wire, was then austenitized in a slow stream of nitrogen at the desired temperature in a vertical tubular furnace and when the required time had elapsed quenched in oil. The two specimens were separated and cleaned of oil by washing in alcohol; the two

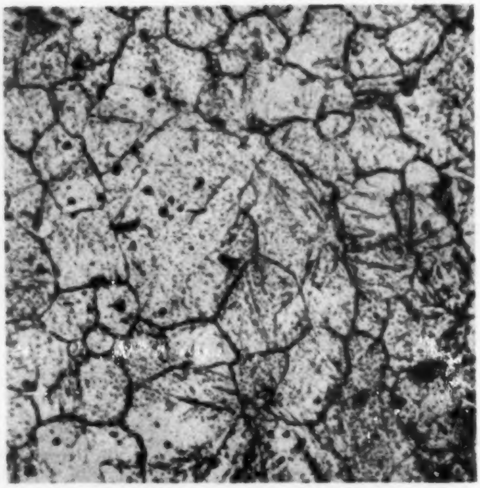


1 *The grain size of the examined ball-bearing steel as a function of austenitizing time and temperature*

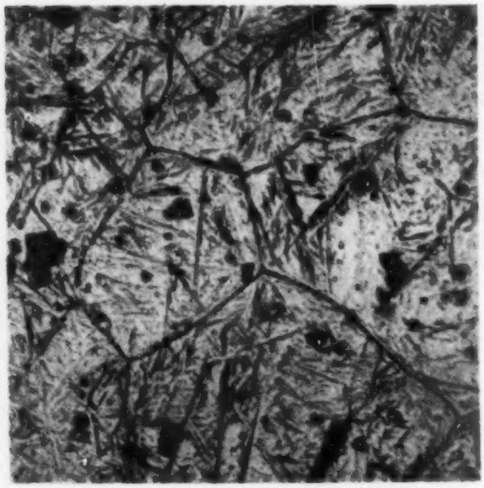
*Report No. 18 of the Working Community for Metallurgy of the Hungarian Academy of Sciences, *Acta Technica*, 1961, **34**



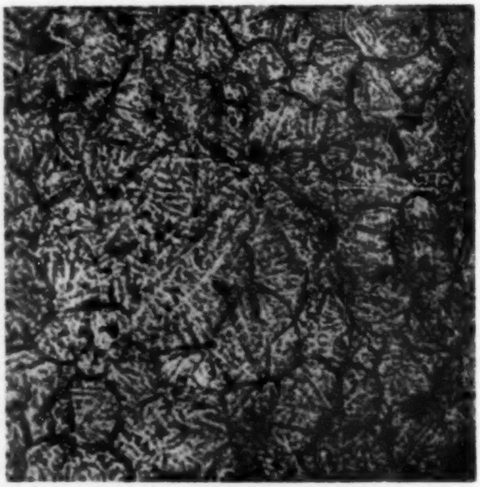
2 *Ball-bearing steel containing 1% C and 1·4% Cr, austenitized at 1,050°C. for half an hour. Grain size ASTM No. 6. Unetched.* × 180



3 *The same as in* **2** *but austenitized at 1,050°C. for an hour. Grain size ASTM No. 5. Unetched.* × 180



4 *The same as in* **2** *but austenitized at 1,250°C. for half an hour. Grain size ASTM No. 2. Unetched.* × 180



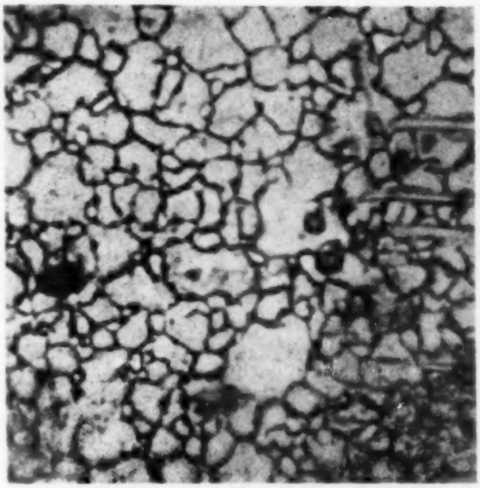
5 *Sample of* **3** *but focused to show the martensitic structure*

identically treated samples were then ready for microscopical examination, as their polished surfaces had hardly deteriorated during heating.

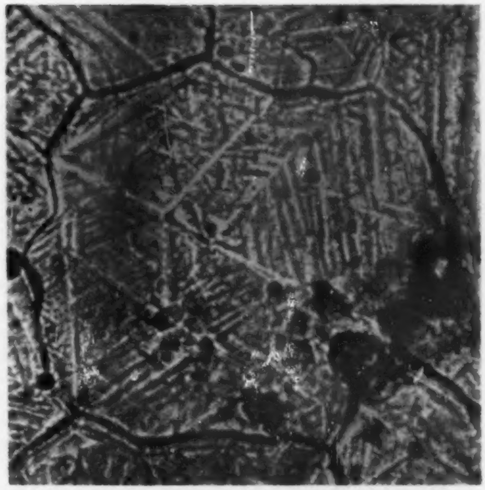
Ball-bearing steel

Figs. 2–5 are micrographs of specimens of ball-bearing steel prepared in this way. The grain boundaries of austenite that existed in the moment of quenching are very clearly visible.

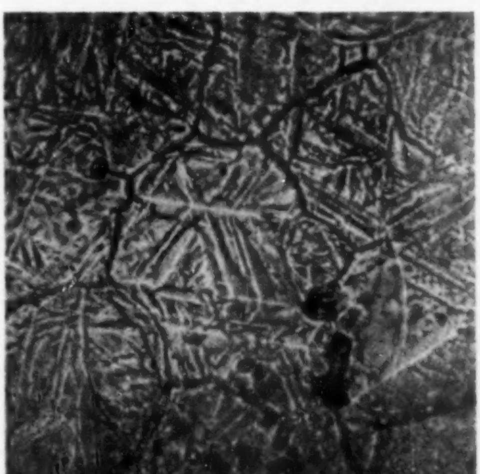
The relief produced by the formation of martensite causes some difference in the appearance of the structure when focused differingly. Fig. 5 is a picture of the very same spot of a sample which also is shown in fig. 3, but was photographed in a



6 *Austenitic grain structure of a 0·12% carbon steel. Unetched.* × 540



7 *Ball bearing steel austenitized at 1,050°C. for an hour. Slight Nital etch after quenching.* × 540



8 *The same sample as in* **7**, *another spot*

9 *Ball-bearing steel austenitized at 1,150°C. for 2 h. Slight Nital etch after quenching.* × 540

position 3–4 μ farther from the objective. In fig. 3 chiefly the grain boundaries, but in fig. 5 rather the needles of martensite protrude.

The method proved quite satisfactory, except when the grain size was finer than grade ASTM No. 12. In coarser austenite grains, larger martensite needles are formed and these make a higher relief, protruding more from the polished plane.

In fig. 1 the determined grain sizes of ball-bearing steel are shown as a function of the austenitizing temperature and time.

Low-carbon steels

In low-carbon steels the relief due to martensite

formation is less pronounced; as shown in fig. 6, the grain boundaries of austenite in a 0·12% carbon steel sample, heated at 1,050°C. for half an hour, are revealed as broad dark lines, which appear to be rather the result of oxidation than that of volume changes accompanying the formation of martensite. Whereas with samples of hard steel nearly the whole area of the polished surface was suitable for examination, with those of low-carbon steel the structure shown in fig. 6 could be found in only isolated spots.

The samples prepared in the way described not only show the austenitic grain size, but after a slight etching with Nital also reveal some interesting details of martensite formation and of the relation of martensite needles to the austenite from which it was formed. Figs. 7–9 are micrographs of lightly etched ball-bearing steel samples. In the centre of fig. 7 there is a large austenite grain, which obviously was a multiple twin having lamellas crossing each other, as indicated by the needles of martensite. In the grains shown in fig. 9, there are long, parallel martensite needles wholly traversing the mother crystal and in the fields between the long needles smaller ones, which were formed in later steps of transformation; within the same austenite grain, the shorter needles run in a few parallel directions.

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(3) O. O. Miller, 'Ferric Chloride Etch to Reveal Austenitic Grain Size in Low-Carbon Steel,' *Metal Progress*, 1949, **56**, 692.
(4) J. Vero, 'The Preparation of Standard Fractures for Grain Size Determination,' *Bányászati és Kohászati Lapok*, 1948, **89**, 1.
(5) P. Széki, 'The Determination by Oxidation of Austenitic Grain Size in Mild Steel,' *Acta Technica*, **21**, Fasc. 1-2, 79-86.
(6) F. Boda, 'Ujabb, egyszeru és gyors eljárás vasötvözetek szemcsenagyságának meghatározására (Simple and quick new method for determination of the grain size of iron alloys),' *Kohászati Lapok*, June, 1957, p. 246 (Hungarian).

'What's in a name?'

What do we understand by the word 'aluminium'? The Aluminium Development Association, in its journal *The Aluminium Courier*, has told us what they hope to see become universal usage.

'Straining after accuracy, scientists and technologists tend to add "and its alloys" after the word aluminium except when referring specifically to one of the grades of pure metal—but this means that a degree of precision needed only sometimes is attained by using a clumsy expression most of the time. Accordingly, in the interests of clarity and simplicity, the ADA now commonly uses the word aluminium in its collective sense, qualifying it as "pure" when the unalloyed metal is intended. It is urged that this practice become universal.

'In thus returning "and its alloys" to store until wanted, another expression, "light alloy," can also be set aside for its proper use in referring to a group of materials—an alloy of one of the metals aluminium, beryllium, magnesium or titanium.'

400-kV. West Thurrock crossing

THE ERECTION and installation of the 400-kV. overhead power link spanning the River Thames between West Thurrock, Essex, and Swanscombe, Kent, which is being carried out for the Central Electricity Generating Board by British Insulated Callender's Construction Co. Ltd., has now reached an advanced stage. The crossing will provide a vital extension of the exsiting supergrid north of the Thames, through the CEGB's new 1,000-MW. steam generating station being built at West Thurrock, to connect with new lines to Canterbury, Lydd, the cross-Channel link and the nuclear power station now under construction at Dungeness. The double-circuit link incorporates six steel-cored aluminium conductors and a similar earth wire. These are the largest of their kind ever used on an overhead power transmission line forming part of the British supergrid.

BIC Construction Co. Ltd., as main contractors to the CEGB, have been responsible for the co-ordination of the design and for the erection of all materials for the crossing with the exception of the foundations which were the subject of a separate contract. The conductors and earth wire were specially designed in collaboration with the CEGB by the Wire Mill Division of BICC who also had overall responsibility for their manufacture. Another member of the BICC Group, Painter Bros. Ltd., has also participated in this project, having fabricated the steelwork for the anchor towers.

The two 630-ft. suspension towers at West Thurrock, which are constructed mainly of high tensile steel and weigh approximately 436 tons each, are 4,500 ft. apart. A major factor influencing the design of these was a Port of London Authority stipulation that the conductors, when erected, should give a clearance of 250 ft. from the mean high-water level of the river. Set 1,600 ft. back from the suspension towers are the anchor towers which are 145 ft. high and weigh 99 tons each. The total route length of the crossing is 7,700 ft. and the precision of the siting of the four towers is such that they are aligned to within ¼ in.

The six conductors and the earth wire consist of a steel core of 91 galvanized steel wires with 74 aluminium wires in two layers stranded over the cores. A final layer of 36 wedge segmental aluminium wires is applied to present a smooth outer surface to reduce aerodynamic effect over the large spans. The overall diameter of these conductors is 2·214 in. and they were manufactured in continuous lengths of 7,754 ft. Each weighs 21½ tons, making a total weight of some 150 tons.

Materials for atomic energy

It was appropriate that the opening address at the Engineering Materials and Design Exhibition and Conference held at Earls Court last month should be by Sir William Penney, K.B.E., deputy chairman, UKAEA. *Many recent developments in materials technology have resulted solely from the requirements of the nuclear power industry, some of which are summarized in this supplementary paper to Sir William's opening address*

IT IS OBVIOUS that industrial and economic progress depends critically on the development of new and improved materials; it is equally important that designers should be able and willing not only to exploit the advantages of these new materials, but also to accept the limitations which they almost invariably have. In order to do this, not only must the development of the materials themselves be coupled with better methods of understanding their basic properties, but the link between scientist and engineer must also be closer. These considerations apply to progress in all industries, of course, but are seen most obviously in those of recent origin. They are particularly true of atomic energy and, in order to illustrate the interdependence of materials and design, this paper describes some examples of the way in which new materials, combined with enlightened design and better basic understanding, have contributed in this field. Most of the examples are metals, since these form a coherent and familiar group, but other types of materials are also involved. It should be emphasized that industry has collaborated very closely with the AEA in the development of these materials, often taking a major role.

The requirements of materials for atomic energy are very complicated. In addition to some particularly unpleasant combinations of the normal problems, such as corrosion, temperature and stress, there are generally at least two other important factors to be taken into account: neutron absorption and the effects of irradiation on the properties. All these factors must enter into a complex multidimensional optimization, since generally none is absolutely paramount and, as usual, the final criterion is an economic one.

Special reference can be made to the problems of fuel element cans. Here, in addition to other factors mentioned above, the cans may often have to accommodate quite severe changes in the volume and shape of the fuel which they contain; these strains may amount to several per cent. linear in complex strain systems and the achievement of the design life may involve straining the cans well into the tertiary creep stage. Since the cans are thin for neutron economy and relatively weak at the peak working temperatures, design must be based on a strain criterion rather than on stress. These features, which are certainly unusual and possibly unique, have led to new ideas and developments in theoretical plasticity and strain analysis. A final special feature of cans is that quality control methods must be extremely rigorous, especially with regard to non-metallic inclusions, because of the high standard of integrity required, combined with the thin sections normally used.

Conventional metals

It is appropriate first to refer to some 'conventional' metals used in atomic energy. With each of these, however, considerable further development has been necessary to adapt them to the special requirements of atomic energy. Such metals include steels, both ferritic and austenitic, aluminium and magnesium. The most familiar of these is mild steel, which has an important application in pressure vessels for gas-cooled reactors.

Mild steels for pressure vessels In the development of the Calder Hall type of gas-cooled reactor, some of the most important advances have come from increased size and power density. This has called for vessels up to about 60 ft. dia., with plate thicknesses over 4 in., which have to be constructed, inspected and stress-relieved on site. These vessels must have a long life and there is, of course, a very high premium on their integrity. The designer must also consider oxidation by the CO_2 coolant and is faced by a range of temperatures which may have creep as a limitation at one extreme and the possibility of brittle fracture at the other.

Brittle fracture is not yet sufficiently well understood for it to be allowed for simply in design and prudence has dictated that we base our practice on the least possible risk. This is done by minimizing separately the possibility of each of the three things necessary to cause a brittle fracture in a steel struc-

ture: a notch, a sufficient stress and a temperature lower than the transition temperature. The notch may be a defect arising from the steelmaking or from the welding, or it may be a design feature resulting in an undesirable stress concentration. The elimination of notches is conditional on the cleanliness of the steel and the excellence of the welding and inspection procedures. The inspection method must be sensitive enough to reveal and locate defects so that they can be eliminated. Freedom from cross-lamination of the plate, particularly in the region of edges of cut-outs where welding is to be done, is easily established by ultrasonic tests or by crack detection and such methods are not invalidated by increase in plate thickness. The use and interpretation of ultrasonic methods of inspection have been so developed that the technique formerly surrounded by controversy is now generally accepted and approved by steelmakers, fabricators, insurance companies and others concerned. For plate thicker than 3 in. multi-curie source gamma radiography is now used extensively on sites and recently the first 5-MeV. linear accelerator developed for use on site has been employed at Trawsfynydd; this device can extend up to at least 6 in. thickness the sensitivity and exposure times obtained with the 2-in. plate used at Calder.

Assuming that some defects or stress concentrations will remain, however, attention must be given to the determination of local stress concentrations and to the energy available to propagate any small crack which might be initiated. The vessels are all stress-relieved after fabrication and readings have been taken from large numbers of strain gauges during this process and during operation. This experience, combined with the wholly favourable history of high-quality stress-relieved vessels, gives a high degree of confidence that a fast-running crack could not be formed. The processes of crack initiation and brittle fracture propagation are difficult theoretically, however, and some fairly large-scale model tests are planned to study the effects of defect size and stress levels on these phenomena.

In the meantime, on the conservative assumption that both the notch and stress criteria for brittle fracture might conceivably be met, the practice is to maintain the vessel temperature above that for brittle fracture so that any fast-running crack would be arrested by the much higher energy absorption of a ductile fracture. In other structures where a transition temperature criterion is applied it is generally by means of a Charpy V-notch test, which is arbitrarily linked with the transition temperature of the structure as a whole. This relationship is not only sensitive to size effects, but varies with the type of steel; in addition, neutron irradiation can increase the transition temperature by a large amount. In order to improve the accuracy of prediction, which in turn determines the minimum temperature to which the vessel may be allowed to fall, tests are now made on all steels used in pressure vessels to measure the temperatures at which fast-running cracks are arrested. Maximum confidence in this test can only be realized when the test is made on large plates of full-plate thickness. To achieve this it has been necessary to construct a 4,000-ton capacity testing apparatus and this will be used in the near future to carry out larger-scale tests on material from all reactors. It is believed that this application of transition temperature theory in design and operation is unique and only justified, of course, because of the special circumstances.

The operational conditions of the reactor must also be limited to avoid any risk of failure from excessive creep deformation which might, for example, result in unacceptable distortion of control rod or discharge tubes; more catastrophically, failure by creep rupture has to be considered. Tests carried out to date have shown that the permissible creep stress in a reactor pressure vessel is less than that which would result from direct application of current design codes, *e.g.* B.S. 1599, and hence it has been necessary to limit the stress in the vessel to a value appreciably lower than a quarter of the ultimate tensile strength. This work has also, incidentally, shown that the high-temperature properties of boiler quality steel are dependent on cast to cast variables and on the effects of heat treatments, especially stress relief procedure. At low deformation rates which are applicable, conventional extrapolation of creep results may be invalidated due to non-linear secondary creep stage and new design criteria have had to be adopted.

Concurrently, extensive research has been undertaken aimed at producing steels having an increased tensile strength, hence allowing increased gas pressures and greater efficiency in future reactors. None of the steels in current production can give the necessary increased tensile strength without sacrifice of, for example, notch ductility, high-temperature strength or weldability, hence the object of the development has been to retain these features, at the same time producing a steel which could be expected to give consistent properties in normal production. Such steels have been developed with tensile strengths increased by about 25% at room temperature; more important, this is accompanied by an increase in permissible stresses at higher temperature without sacrifice or either notch ductility or weldability.

Austenitic stainless steels Austenitic stainless steels have three main uses in atomic energy: in chemical plant, in pressure vessels for water and liquid-metal cooled reactors and as fuel element cans.

After uranium fuel elements are irradiated, they are processed by wet chemical methods at Wind-

scale. Due to the presence of fission products, the solutions are extremely radioactive. Some stages use strong nitric acid at boiling point, under circumstances which are corrosive in the extreme. When the plant was built, no suitable steel was available and a new one was developed which was completely austenitic in character with superior corrosion resistance; this steel contains 18% chromium, 13% nickel and 1% niobium and new techniques had to be developed for its fabrication. In the study of the corrosion behaviour of this steel it was evident that a concentration of chromium in the nitric acid in the hexavalent state and also fission elements, such as cerium and ruthenium, in their highest state of valency accelerated the corrosion to a marked degree. Latterly it has proved possible to have limited access to part of the plant and carry out some inspection and the corrosion effects were much less than had been anticipated. Further study showed that the presence of beta and gamma activity of the fission products led to the radiochemical decomposition of the nitric acid and water and, therefore, acted contrary to the accelerated effect of the fission products. The decomposition products and chemical equilibrium set up in the system will be complex, but the overall effect of the irradiation is that no accelerated corrosion is caused by the presence of ions which in the absence of irradiation would bring this about. This is one of the very few instances where radioactivity has eased a problem.

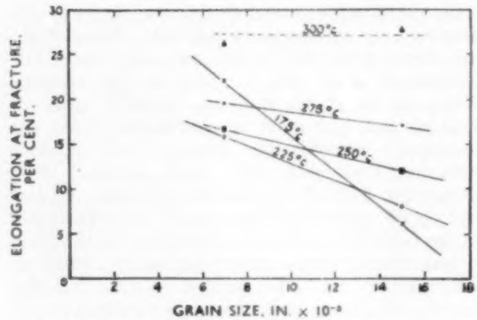
Stainless pressure vessels are often made of clad ferritic steels and, apart from the problems of fabrication in large sizes and complicated shapes, must often withstand very corrosive conditions, and there are the usual problems of water control and stress corrosion; with sodium or NaK very low oxygen levels are necessary. Irradiation effects are, however, not now thought to be very important, since the oxidation/corrosion effects do not seem strongly affected and changes in mechanical properties are not very marked.

For cans, stainless steel must usually be very thin because of its high neutron absorption; wall thicknesses of 0·010–0·020 in. are common and developments are in hand down to 0·005 in. or less. In CO_2-cooled reactors the oxidation resistance at reactor temperatures of standard 18/8 is marginal, especially as some intergranular penetration is observed, so that extrapolation to very long times is difficult. The cans must, of course, be weldable to very high standards. It also appears that irradiation may stimulate the precipitation of the sigma phase, which is a common problem in high-temperature usage and leads to loss of ductility. For these reasons a new version of austenitic steel has been developed containing 25% Ni, 20% Cr and 1% Nb. In addition, the requirement of cleanliness has led to the use of advanced melting techniques, such as repeated melting in vacuum arc or H.F. furnaces. The improvement in cleanliness led, incidentally, to some unexpected changes in other properties, but these have now been taken into account.

Magnesium Another conventional material adapted for nuclear use is magnesium. The early design studies for the Calder Hall reactors showed that, in order to use natural uranium and achieve temperatures of interest for power reactors it was essential to adopt magnesium canning instead of aluminium, as used in the earlier gas-cooled Windscale reactors. Magnesium did not seem at first sight a very attractive engineering metal. However, some small-scale alloying studies showed that magnesium could have quite remarkable oxidation resistance both in air and CO_2 and these results were an important factor in the decision to go ahead with the Calder Hall project. Further development work and the needs of mass production revealed other difficulties. For one thing, the alloying elements introduced to improve the oxidation resistance tended to provide undesirable inclusions or to make weld cracking more likely. Satisfactory compromises were reached in the laboratory, but in large-scale production completely new standards of cleanliness were necessary, especially since magnesium is invariably melted under a rather corrosive flux which would be a most undesirable inclusion in can walls. Because of the rather erratic distribution of any inclusions, highly complicated statistical sampling and non-destructive inspection methods had to be devised to assess the material at intermediate stages. In the event, over many tens of thousands of Calder elements, no failure has resulted which can be attributed to flux inclusions. Another production problem was the fabrication of complex shapes. Although the earliest cans were machined from solid bar extrusions, all the current shapes can be made either by extrusion or by fin-rolling, a quite remarkable achievement with this metal.

The most fundamental problem, however, in the use of magnesium is its ductility in the range 200–300°C., where it may be subjected to creep strains in the reactor. It is now known that such strains create grain boundary cavities which may coalesce to form tiny leak paths. The strain levels at which cavitation causes failure depends rather crucially not only on the strain rate and temperature, but also on material variables, of which grain size appears to be most important. Fig. 1 shows the rather complex way in which ductility varies with temperature; as noted earlier, it is advantageous to utilize a very high proportion of this available ductility. By means of grain-size control and choice of gas-inlet temperature, adequate ductility can be provided to give confidence that the civil fuel elements will have

satisfactory endurance in this range, but the margin can never be very great and there will always be a need for designers to have a close appreciation of the problems. As is often the case, the problems in the hot parts of the fuel channels are quite different. Here, creep deformation of heat-transfer surfaces in the gas flow is the main problem and, since maximum creep strength and ductility at lower temperatures may not be obtained in the same material, it may be advantageous to provide two different types of fuel elements, although this naturally limits the flexibility of fuel cycles.



1 *Effect of grain size on creep ductility of Magnox A.12 in 1,000-h. tests at various temperatures*

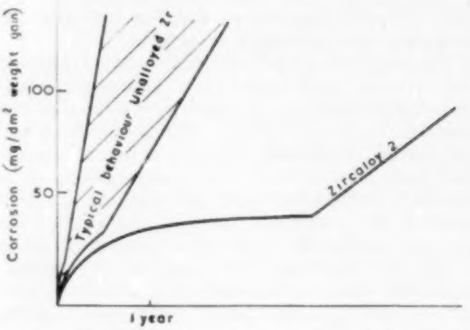
Newer metals

Several metals, which were in little or very specialized use a decade or two ago, have been developed mainly or solely because of their atomic energy interest; these include the fuel metals uranium, thorium and plutonium and such structural metals as zirconium, hafnium, niobium, vanadium and beryllium.

Uranium Generally, the reason why these ' newer ' metals have not been used before is that they are usually difficult to extract and chemically reactive; often they have structures with poor mechanical properties and are toxic. Uranium metal provides a good example of all these difficulties; the reduction of its compounds is very difficult and the product may be either grossly contaminated or, if finely divided, pyrophoric. It oxidizes rapidly at moderate temperatures and it is, of course, toxic. It has three allotropic forms between room temperature and 800°C., the R.T. form being described as ' orthorhombic with the atoms arranged in corrugated sheets.' As might be expected, this is not a favourable arrangement from the mechanical properties point of view, especially as it is highly anisotropic. In addition, uranium suffers special irradiation damage effects which in their extreme forms are quite spectacular. Nonetheless, as is well known, these problems have been overcome or circumvented so that the first stages of the U.K. atomic energy power programme comprising several thousand megawatts of installed capacity are based on uranium metal fuel. The production of uranium bars is established in the U.K. on a scale of thousands of tons per year and the product has a purity and reproducibility of a very high standard compared with other metal industries. Furthermore, the behaviour of these bars, now running into hundreds of thousands for the Calder and first civil reactors, is in close accord with predictions and design requirements, greatly strengthening the confidence in the economic future of these stations.

Zirconium Although zirconium has been used for some time in certain special applications in chemical plant in small amounts, its present importance is due almost entirely to its reactor use, especially in water-cooled reactors; conversely, it might almost equally be said that the status of the water-cooled reactor, which is much the most important type in the U.S., rests largely on the properties of zirconium. Zirconium has a low neutron cross-section and, although its mechanical properties fall off rather rapidly at moderate temperatures, they are quite adequate for current water-cooled reactors. The corrosion resistance of pure zirconium can be remarkably good in high-temperature water (say 325°C.), but it was soon found that the resistance of material produced to commercial standards varied greatly. The film is normally very protective, so that corrosion proceeds at a continuously diminishing rate, but in certain samples at a limiting film thickness this protectiveness is lost and corrosion continues at a linear rate which may be unacceptably rapid. This transition is called ' breakaway ' and alloys have been developed in order to delay breakaway beyond the required service life for the design conditions of temperature and pressure. Again, this is a rather neat optimization and further progress in this reactor field is linked with the development of newer alloys. Fig. 2 shows some typical corrosion rate curves.

As temperatures go up, with in-core boiling or steam cooling, an additional problem is that increasing amounts of hydrogen, formed radiolytically or by corrosion, may be absorbed by the zirconium. This hydrogen may precipitate as zirconium hydride, with detrimental results on the ductility, especially under impact; where thermal gradients exist the hydrogen could be absorbed mainly in the hotter portions and might then diffuse quite rapidly down a thermal gradient and precipitate in the colder parts. For complex reactor structures, such as an array of pressure tubes requiring a very long life, this is clearly another finely balanced design problem, especially as impact ductility is so difficult to allow for. In such a reactor system a difference of only 20°C. in peak temperature may have a deter-



2 *Corrosion of various types of zirconium and Zircaloy in high-temperature water*

mining influence on the processes of corrosion and hydrogen absorption and, unfortunately, this margin might be crucial to the economics also. There are good reasons to hope, however, that alloy advances will provide a reasonable scope for further engineering development.

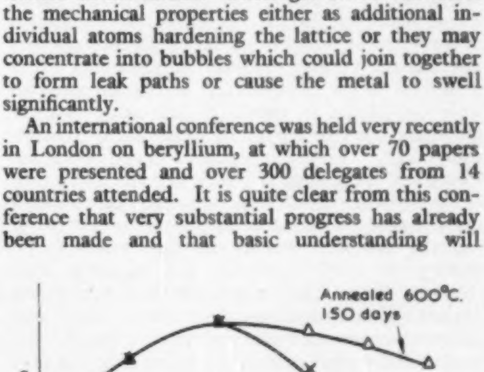
Zirconium seems to be essential also in the homogeneous aqueous reactor, for use in the inner container in order to allow neutrons to penetrate into the blanket. Here, an unusual problem was experienced. Although the corrosion reaction between high-temperature water and zirconium is little affected by normal radiation, it was found that corrosion rates were greatly increased when the solution contained fissile atoms. In this case the protective nature of the film was totally lost and the rate of attack was not only linear from the outset, but was almost directly proportional to the fission density; it is thought that the main factor is the absorption of fissile atoms into the oxide film, which is then disrupted by the fission process. Although it seemed that a compromise could be reached which would not be too uneconomic between the rate of attack and the reactor power density, in practice it was found that coolant flow inequalities could lead to the ' plating out ' of fissile atoms and holes were formed very rapidly in these places. It is claimed that this problem can be overcome by better flow distribution and, although this may be true, it is probably fair to say that this experience has been largely responsible for halting the development of this type of reactor.

Hafnium In nature zirconium always occurs with a small percentage of hafnium, which has a very large cross-section and must be removed before the zirconium is made into metal for reactor use. Since the two elements are very similar chemically, their separation was not easy, but several satisfactory methods were developed. Fortunately, this application yields a bonus for once; because of its high cross-section and similarity to zirconium in behaviour, hafnium is a very suitable control material for certain water reactor applications and the demand for it is at least as great as the supply, which, of course, depends on the output of reactor grade zirconium.

Beryllium Beryllium is a very special case. Although it is fair to say that atomic energy has taken a leading place in its development, the future may show that it has at least equal potential in other spheres, especially in the space programme. Here its high strength/weight ratio is its main attraction, but its comparatively high melting point and exceptional heat capacity are also desirable features. For atomic energy work, in addition to these properties, beryllium has much the lowest cross-section of any metal likely to be used in reactors in the foreseeable future.

Beryllium has its own very severe problems, of course; it seems that nature does not intend her rewards to be too easily won. For general use the main problem, apart from its toxicity, is its lack of ductility in certain conditions. This is not only apparent around room temperature, but there is also a second minimum in the temperature ductility curve in the region around 600°C., which is particularly important for reactor usage. In addition, for reactor application, there is also the problem that nuclear reactions can generate helium and tritium in the lattice. These gas atoms can affect the mechanical properties either as additional individual atoms hardening the lattice or they may concentrate into bubbles which could join together to form leak paths or cause the metal to swell significantly.

An international conference was held very recently in London on beryllium, at which over 70 papers were presented and over 300 delegates from 14 countries attended. It is quite clear from this conference that very substantial progress has already been made and that basic understanding will



3 *Effect of temperature on ductility for normal and heat-treated beryllium*

advance over the next few years very rapidly, leading to important technological improvements. For example, it is already clear that ageing processes are involved in the 600°C. ductility minimum and that this minimum can be removed in tensile tests at least by a suitable combination of small alloying additions and heat treatment. Fig. 3 shows this. There is clearly great promise in this approach, but whether this particular method will retain its advantages under all conditions remains to be seen; for example, such treatments to gain ductility may well affect other properties, such as corrosion and creep, also and compromises may have to be worked out.

Much progress has also been made on understanding the room temperature brittleness of beryllium. Many workers in this field now regard beryllium as showing a 'tough-to-brittle' transition of the same general type as shown in many metals (notably mild steel) with a transition temperature in normal circumstances at about 200°C. Efforts to reduce this transition temperature, and to raise the degree of ductility at room temperatures or slightly above are meeting with some success. The achieving of useful ductility at temperatures in this range (*i.e.* the 'rubber-forming' range) might well be important in the fabrication of beryllium sheet for use in aircraft or rockets.

Niobium In the earliest days of the Dounreay fast reactor project it was evident that compatibility considerations, especially in the event of the uranium fuel becoming molten during use, placed severe limits on the use of conventional materials as fuel element sheaths. In the search for a suitable material the periodic system was examined. The principles of the compatibility of reactor materials were considered in terms of their alloy systems, including the free energy of formation of possible compounds. In the absence of experimental information, metallurgical theory and the application of the periodic classification indicated that a suitable metal would be found in Group 5A or 6A of the periodic system. Within the time available for making the choice, niobium and vanadium were selected. At this time the availability of niobium was limited and small amounts of impurities, which were difficult to remove, tended to make it brittle. Intensive study soon established on an adequate scale methods of extraction and purification leading to very pure material of high ductility.

Using the newly established techniques for niobium, vanadian was also obtained for the first time in the U.K. in a pure and ductile form. The work on these two elements gave particular satisfaction to the scientists and technologists involved because here was a branch of engineering where theory forecast the necessity for an element which was not then commercially available and the application of research and development into the extraction metallurgy and fabrication studies showed not only that the predictions were valid, but also that the solutions were technically feasible.

Fabrication is initially by power metallurgy and the vacuum high-temperature sintering process allows a substantial reduction in the level of impurities, such as hydrogen, nitrogen, carbon and oxygen. Such material can then be forged into bar and made into sheet or tube by conventional techniques. Sufficiently pure material can be cold worked 99% without interstage annealing, the material increasing in hardness from about 70 to 170 V.P.N. Niobium is also ductile in the recrystallized state and has a considerable advantage over commercially available tungsten and molybdenum, which are not.

Although niobium is a body-centred cubic material, the brittle ductile transition of the pure metal is at least 200°C. below room temperature. However, oxygen, nitrogen, carbon and hydrogen can dissolve interstitially in the metal and considerably modify its tensile and impact properties. Thus 1,000 p.p.m. oxygen will raise the hardness to 150 V.P.N. and substantially reduce the energy to fracture. With increasing temperature such impurities have less effect on mechanical and impact properties, though strain ageing effects have been observed in the range 160–300°C.

Despite its good high-temperature tensile and creep properties, niobium shows poor oxidation resistance in oxidizing media (air, CO_2, water, steam) at temperatures much above 300°C., so that it is not suitable for use in gas-cooled reactors. For liquid metal cooled reactors, where the oxygen and hydrogen impurity content of the sodium coolant can be controlled to a very low level by cold and hot trapping, niobium has an important application as a canning material, possessing high strength and compatibility with uranium at temperatures above those feasible for the use of stainless steel or Nimonic type alloys. Fabrication of niobium cans, including welding, has been successfully developed on a routine basis for the Dounreay fast reactor.

For non-nuclear applications the development of niobium alloys of improved oxidation resistance may offer the possibility of their use under service conditions where high-temperature strength is essential. The other potential application of niobium is in chemical plant where corrosion resistance to nitric acid or hydrochloric acid media is required.

Ceramics

Although these remarks so far have been devoted to metals, it is rapidly becoming more certain that the future in atomic energy will see increasing emphasis on the use of ceramics. This will involve a substantial expansion of the basic mechanisms of their physical and mechanical properties so that

these may be exploited by designers in a manner similar to metals.

This trend can be exemplified by graphite. The main use for graphite in reactors to date has been as a moderator. In this application the chief requirements have been for extreme purity and reasonably high density, with relatively less emphasis initially on physical and mechanical properties. The questions of energy storage and growth due to the irradiation damage processes and the resistance of graphite to oxidation in CO_2 under irradiation have, of course, been pursued very thoroughly, but as temperatures are increased the complexities of growth and its relationship with creep are becoming increasingly important. Graphites with improved properties have been produced, but the use of these materials in the early U.K. reactors has been retarded because changes in the dimension of these materials under irradiation could not accurately be predicted; experimental determination of these changes is a lengthy and expensive process. However, our fundamental understanding of the factors controlling irradiation-induced dimensional changes in graphite is improving rapidly and it now appears probable that we can manufacture graphite which is much more dimensionally stable than Grade 'A' material and also has higher density, lower permeability, greater strength and improved resistance to in-pile oxidation.

In more advanced reactor designs graphite may become a more integral part of the fuel assemblies, as in the Dragon reactor. Here not only are the conditions of temperature and irradiation much more severe than in other gas-cooled reactors, but the mechanical integrity of the structure is clearly of paramount importance. Another vital feature is that of containing the fission products within the fuel elements and this has led to the development of graphites with permeabilities many orders of magnitude lower than hitherto. It remains to be seen whether these impermeable graphites provide a full solution for this problem, but they may be of great interest in other spheres.

Ceramics are often thought of as completely brittle—'as brittle as glass.' However, it has been found in recent years that even at room temperature certain ceramics, *e.g.* magnesia, are ductile as single crystals, although they still appear to be brittle in their polycrystalline form, and the reasons for this are being investigated at the moment. At elevated temperatures even polycrystalline ceramics can deform under the appropriate stress conditions by quite regular mechanisms, such as movement of dislocations and grain boundary sliding, *e.g.* greater than 3% deformation has been obtained in compression creep tests on BeO samples at about 1,370°C. In addition, minor variations in composition of UO_2 can greatly influence its plasticity, although the mechanism of this is not clearly understood at present.

Examination techniques

As noted above, the development and utilization of new materials depends critically on new techniques for studying these materials, both to understand their basic properties and to improve their reproducibility. Some examples of inspection techniques have been mentioned above, including ultrasonics. In this latter field great progress has been made, not only in improving the reproducibility and sensitivity of the method, but also in the range of its application. In uranium bars, for example, the measurement of the attenuation of sound waves can be used to check the grain size; because of the anisotropy of the uranium crystal, measurements of sound velocity in different directions can detect small amounts of preferred orientation. Ultrasonic methods have also been developed, together with dye penetrant and eddy current methods, to reveal the presence of small cracks or inclusions in thin-walled stainless steel cans. An interesting facet of this work is that the sound image can be converted into a visual image which will indicate the presence of defects in the material in a particularly helpful way; this forms the basis of the so-called ultrasonic camera.

A general problem in atomic energy work is the radiography of components after irradiation, when they may be extremely active emitters, especially when fuel is involved. X-radiographic techniques utilizing suitable shutters, projection methods and special emulsions have been developed for radioactive components emitting up to 300 roentgens per second at the X-ray film. Developments using high-energy accelerators or neutron radiography are expected to extend the range to even higher activities.

New spring alloy

Johnson, Matthey & Co. Ltd. announces the development of Mallory 53, a nickel-silicon-copper alloy that fulfils the need for a spring material with mechanical properties at least equal to those of the conventional phosphor bronzes and brasses, but with appreciably higher electrical conductivity. The need for a spring material with such characteristics has been felt for some time by designers of electrical equipment, especially those involved in the production of miniaturized components.

Because of the exceptionally high electrical conductivity of the alloy, 40–45% I.A.C.S., it is possible for springs of small section to carry appreciably larger currents when made in Mallory 53 alloy than when made in phosphor bronze. Advantage can be taken of this characteristic to increase the current rating of existing designs of springs. All spring-forming operations can be applied to Mallory 53 after heat treatment, and hence the alloy is supplied in the precipitation-hardened condition requiring no further heat treatment by the user.

A data sheet, 1300 : 332, giving details of the characteristics of the alloy and the forms in which it is supplied, is available on request to the company's head office at 73–83 Hatton Garden, London, E.C.1.

Britain's biggest die-forged aluminium propeller blade

THE BIGGEST DIE-FORGED aluminium propeller blade yet made in Britain was recently produced for the de Havilland Aircraft Co. Ltd., who are supplying the propeller equipment for three prototype Transall C.160 aircraft ordered for the French and German Air Forces.

The de Havilland 4/8000/6-type propeller, with a diameter of 18 ft., was specially designed for the Transall C.160 and is the result of six years' intensive design and development work on the Tyne turbine engine. The propeller hub, which incorporates the familiar features of Hydromatic design, also embodies a number of improvements necessitated by the characteristics of the Tyne turbine engine. The basic unit upon which the propeller is built is the 'spider'—a high-tensile steel forging accurately machined to fit the engine propeller shaft. The four aluminium alloy blades are retained on the arms of the 'spider' by a high-tensile steel barrel of two-piece design, upon which the pitch-change mechanism is mounted.

The solid aluminium-alloy propeller blades, of double-taper plan form, are machined from forgings produced at the Handsworth (Birmingham) Works of Alcan Industries Ltd. on their 45,000-lb. forging hammer, the largest pneumatic hammer in Britain.

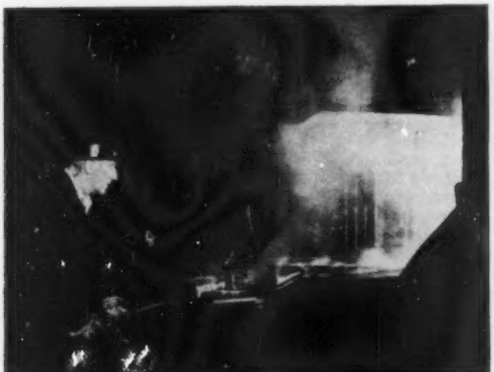
The blades are made from extruded forging stock in Noral 17S alloy chosen for its special properties. As manufactured, the forging stock is cylindrical in form 87 in. long, 8½ in. in diameter, and 500 lb. in weight. Prior to forging, the stock is scalped to a diameter of 7½ in. and one end is machined to provide a 7-in. long tong hold. The stock is then soaked in a pre-heat furnace, and having been brought up to a temperature of 450°C., at which point it is malleable, it receives the first of three part-stampings in the preparation dies of the forging hammer, alternated with intermediate pre-heats. The part-forged blade is closely inspected between each operation and the excess metal, or 'flash,' is removed.

This pre-heat/part-stamp sequence continues with the finishing dies, after which the tong hold is removed and the hub machined. At this point the blade measures 108 in. in length with a maximum width of 19½ in. After a further soaking in the pre-heat furnace, the blade is placed in an upsetting press where the steel thrust rings are retained on the shank by an upset flange.

The upsetting operation, which reduces the length of the blade to 105 in., is followed by solution heat treatment (the metal ageing naturally at room temperature and reaching its maximum properties after about five days), truing of the blade and ensuring a twist of 48½ deg., and finally polishing of the thrust rings. The weight of the blade on leaving the forge is 350 lb.

At the de Havilland Company's works at Stevenage the blades are machined to a maximum width of 18·4 in., after which they are anodized.

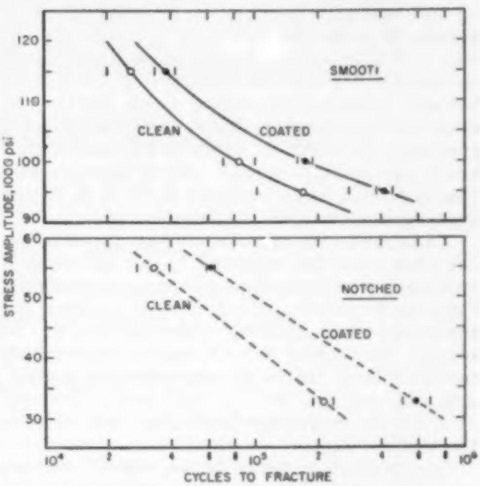
Striking the aluminium propeller blade in the 45,000-lb. forging hammer at the Handsworth, Birmingham, Works of Alcan Industries Ltd.



Fatigue crack propagation in metals

According to a recent study by W. L. Holshouser and H. P. Utech, of the mechanical metallurgy laboratories, U.S. National Bureau of Standards, the rate of fatigue crack propagation through a metal specimen is significantly reduced by the presence of an organic liquid, such as dodecyl alcohol. The studies were sponsored by the U.S. National Aeronautics and Space Administration in order to investigate the role played by surface reactions in fatigue failure, a phenomenon that may occur in any material subjected to alternating stresses.

Fatigue failures are progressive and consist of two phases, the first, crack initiation, extending from the start of the stress application to the appearance of the first crack (which ultimately causes specimen failure); the other, a period of crack propagation, which terminates with the abrupt fracture of the piece. In a laboratory test the duration of each phase depends on the type of specimen used. In earlier Bureau work with smooth cylindrical specimens it was found that the presence of a certain polar organic liquid on the surface of the specimen increased the fatigue strength of several metals. This improvement was primarily a measure of the effect of the liquids on fatigue crack initiation, since a large portion of the total life of the specimens had been expended before cracks appeared. The reason for the improvement was thought to be that the polar compounds formed films on the metal, which prevented deleterious reactions between the metal and the atmosphere.



1 *S-N curves obtained on both smooth and notched specimens of 4340 steel*

To obtain information on the effect of such compounds on the crack propagation phase, fatigue tests were conducted with sharply notched cylindrical specimens in both a clean condition and with dodecyl alcohol on the surface. The notches serve as stress raisers; as a result, the effective stress at the root of the notch greatly exceeds the nominal

Table 1 *Results of tests to determine the effect of dodecyl alcohol on fatigue crack propagation*

Material	Nominal stress amplitude (1,000 lb./sq. in.)	Thousands of cycles of stress: Clean (a) Nf	Clean (b) Nc	Clean (c) Np	Coated with dodecyl alcohol (a) Nf	Coated (b) Nc	Coated (c) Np	Ratio Np values, coated/clean
4340 steel	32·5	210	10	200	586	10	576	2·9
	55	33	2	31	63	2	61	2·0
Cu-Be	30	749	78	671	3,406	78	3,328	5·0
	50	27	3	24	39	3	36	1·5
6061-T6 aluminium alloy	11·5	358	18	340	632	18	614	1·8
	17	81	4	77	120	4	116	1·5
17-7 PH stainless steel	42·5	115	40	75	325	40	285	3·8
	52·5	32	12	20	39	12	27	1·4

(*a*) Nf = Median fatigue life (five to seven specimens).
(*b*) Nc = Number of cycles required to produce a detectable crack.
(*c*) Np = Nf − Nc (crack propagation portion of fatigue life).

stress applied to the specimen, and cracks appear at the notch at an early stage of fatigue life.

Testing procedure

In the study, tests were conducted on specimens of 4340 steel, 17-7 PH stainless steel, 6061 aluminium alloy, and a copper-beryllium alloy (1·75% Be). They were 0·365 in. dia. and notched around the middle to a reduced diameter of 0·250 in. To prevent variations in surface finish and in the amount of cold work produced in the surface of a specimen, the 0·005-in. radius at the root of each notch was carefully ground. All of the tests were run on rotating-beam machines of the R. R. Moore type, operated at 3,000 rev./min.

To determine the approximate point in the fatigue life when cracks first appeared, fatigue specimens of each metal were tested for small percentages of their expected fatigue life, and longitudinal sections of the specimens were examined metallographically for cracks. An analysis showed that the approximate portion of total fatigue life expended before cracks appeared was 5% for the steel and aluminium, 10% for the copper-beryllium alloy, and 35% for the stainless steel.

Specimens to be tested in the coated condition were first stressed in the clean condition for the duration of their crack initiation period, and then for the remainder of the fatigue life dodecyl alcohol was dripped into the notch. Data for all four alloys show that the duration of the crack propagation period at two stress levels was increased by the dodecyl alcohol coating (table 1).

The results indicate that the coating, by limiting the access of molecules of oxygen or water to the metal surface, reduces the rate of detrimental surface reactions that normally occur when specimens are stressed in air. Two materials, the aluminium and stainless steel, showed a greater beneficial effect with notched specimens than they did with smooth specimens in the earlier study. This result may be associated with the relatively impermeable and adherent oxide films that form on these metals. Prior to crack initiation these films apparently minimize detrimental surface reactions. During the crack propagation phase, however, each increment of crack extension provides an area of clean metal surface that may react with any oxygen in the atmosphere.

While these considerations provide a possible explanation for the effects of dodecyl alcohol coatings on crack initiation and propagation, the mechanism of the effect of surface reactions on fatigue is still not clear. Recent work, both at the Bureau and elsewhere, tends to show that the oxygen and the water vapour in the atmosphere are responsible for the reduction in fatigue life. Nevertheless, little explanation can be offered as to the manner in which these components accomplish the reduction until more is known about the entire fatigue process.

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GAS NITRIDING OF STAINLESS STEEL

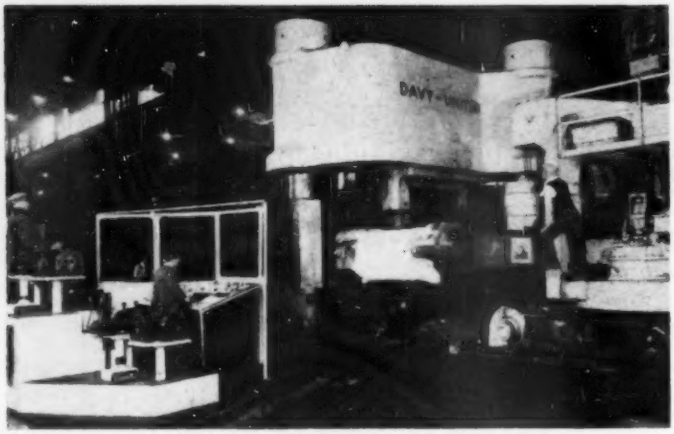
In nitriding stainless steels inconsistent results are usually obtained unless some method is used to remove the surface oxide film which is believed to act as a barrier to nitrogen penetration. One widely used method is to sand or vapour blast the parts and then pickle them in acid. Although effective, this technique and others, whether electrolytic or chemical, increase production costs appreciably.

At Cameron Iron Works preparation of the surface by pickling and other means is no longer required, according to V. J. Coppola, formerly with Cameron Iron Works, Houston, Texas, U.S.A., reported in *Metal Progress*, July, 1961. Finish-ground or lapped parts are nitrided directly in a retort which is sealed and purged of air before heating. In practice, an absolute purge is neither practical nor necessary; however, to assure satisfactory nitriding, not more than 3% air (by volume) is permitted to remain in the retort before it is heated.

The procedure which allows direct nitriding is based on tests with Type 410 stainless steel to determine the effect of various temper films (and a passive oxide film) on nitriding. Results indicate that a passivating film and temper films produced at 480°C. or above do not affect the depth of the case. It was found that when the purge of the retort was inadequate an oxide formed when the parts were heated to the nitriding temperature. When this occurred, even surfaces that had been very carefully prepared failed to nitride.

It was also found that the length of time between final surface preparation and nitriding did not affect nitriding.

The successful results obtained when nitriding lapped or smoothly ground surfaces, without further surface preparation, have been attributed to the removal of a small but critical amount of disturbed or worked surface metal. It is virtually impossible to nitride stainless steel that has been machined by turning, milling or coarse grinding without special surface treatment because of disturbed metal. These surfaces can be ' activated ' by a mild peening action, such as sand or vapour blasting. This beneficial effect on the nitriding reaction is not too clearly understood; it is only known that blasting induces compressive stresses in the surface which may counteract, to some extent, the tensile stresses developed during machining.



3,000-ton forging press at Walter Somers

WHEN PLANS were prepared to replace the 3,000-ton forging press at the works of Walter Somers Ltd., Halesowen, it was decided that, although existing presses were powered by steam, the new press could more efficiently be powered by electricity. The cost of converting two other existing presses of 800-ton and 1,500-ton capacity from steam to electricity would have been, however, too expensive. It was, therefore, decided to install thickness control on the new 3,000-ton press. This would enable the one 3,000-ton press to undertake the work of the previous three presses without the risk of over-forging a small workpiece which would normally have been forged on one of the smaller presses.

In view of the many advantages of the two-column inverted press over the conventional four-column press this design was decided upon. Some of the advantages are: (*a*) Saving in height, (*b*) better access to press tools, (*c*) improved view by the operator, (*d*) improved stability, (*e*) less risk of fire and (*f*) more compact housing of electrical and pumping equipment.

The new press is then a two-column, oil-hydraulic, three-stage drawdown press, with three hydraulic working cylinders in line.

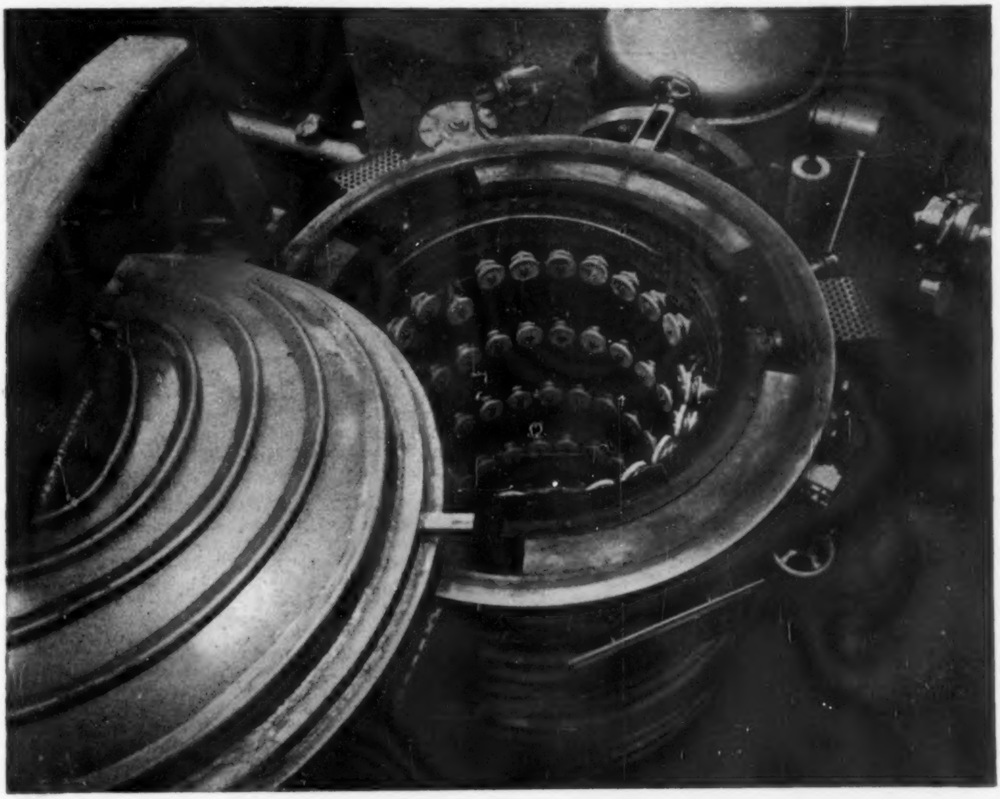
The press can be used with an effort of either 1,000 tons and a press speed of 7·5 in./sec., or 2,000 tons with a press speed of 3·75 in./sec., or at its maximum thrust of 3,000 tons and a press speed of 2·5 in./sec. The approach speed is 9 in./sec. and the return speed 14 in./sec. The press columns are set at 14-ft. centres on a centre line at an angle of 30 deg. to the centre-line of the sliding anvil. This gives the operator a completely clear view of the work under the press. There is 12 ft. of daylight between the top moving crosshead and the sliding anvil plates and the press stroke is 7 ft. The anvil is carried on hydraulically powered sliding plates and the complete bottom tooling with the forging in position can be moved a total distance of 14 ft. or 7 ft. each side of the working centre-line. In addition, the press has tool change gear enabling a complete set of tools to be changed in a matter of minutes.

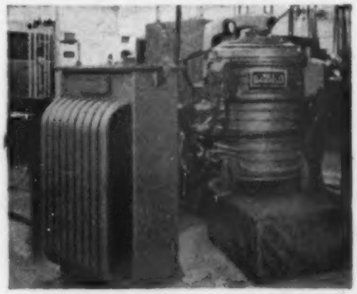
There are six pumps driven in pairs by motors of 500 nominal h.p. each, with a peak horsepower of 1,000 at a working pressure of 4,500 lb./sq. in. The pumps each deliver 150 gal./min. of oil when running at 1,500 rev./min. These pumps are installed in the foundations below the press, as also is the hydraulic valve gear for controlling the working tonnage and the stroke of the crosshead and tools.

The control desk is located square with the press anvil, allowing the operator an uninterrupted view of the forging. Immediately behind the control desk are the control positions for three overhead cranes. These controls are of a type developed by BISRA and control a 30-, 60- and 100-ton crane respectively. There is in addition to the cranes a floor-mounted 13-ton manipulator, independently controlled, for the handling of certain types of forgings.

A maintenance panel, located at some distance from the press, indicates to the maintenance staff that motors, pumps and ancillary equipment are operating satisfactorily.

As this single press will deal with the whole output of the department, which formerly needed three presses of varying sizes, the furnace capacity has had to be increased and the new press will feed from ten furnaces.





NEWS

200-ton gas-fired stress-relieving furnace

A TOWN'S GAS-FIRED bogie-hearth stress-relieving furnace has recently been commissioned in the Darlington works of Whessoe Ltd. It is believed to be the largest of its type in the British Isles and probably in Europe.

The furnace, supplied by Dowson & Mason Ltd., is designed to stress relieve welded fabrications at temperatures between 600–650°C. and perform other heat-treatment operations up to a maximum of 1,150°C.

The internal dimensions are 18 ft. wide, 21 ft. 9 in. high from the top of the bogie to the crown of the furnace arch, and 85 ft. long between the door faces.

In large furnaces there is a considerable build-up of pressure in the upper portion of the chamber, due to the great height and the temperatures of operation (up to 1,150°C.). It is important that gases are prevented from escaping from the top and upper sides of the furnace doors and, for this reason, sandseal troughs are arranged across the top of the roof at the door faces and dipper castings on top of the doors complete the seals. At the sides of the door openings there are asbestos insulation sealing pads, and both doors when in the closed position are clamped by hydraulic cylinders, since tightening by hand would not be very satisfactory.

It is also important in very large furnaces to prevent the ingress of air from below the bogie and, for this reason, fixed sand troughs are arranged along the sides, with dipper castings in the furnace walls making the seals. Hinged sand troughs at each end are raised by cams to make seals at the bottom of the doors. This allows the bottom of the bogie to be open from end to end, for keeping the wheels and axle boxes cool.

The bogie is moved by a wire cable haulage gear driven by a 25-h.p. electric motor. To reduce tractive effort, roller-bearing axle boxes are used and the wheels are disposed alternately in four rows to ensure the maximum charged weight of 200 tons is evenly distributed.

The walls, roof and doors are lined with insulating refractory, as its low-thermal storage gives considerable fuel economy in the intermittent heat-treatment processes on which this furnace will be operated. A frequent problem encountered in the design of large furnaces is that of preventing the walls from collapsing inwardly. Such collapse is impossible in this furnace, because taper wedge bricks are used at intervals along the sides and in the doors. These are held to the casing by vertical rods passing through holes in the bricks.

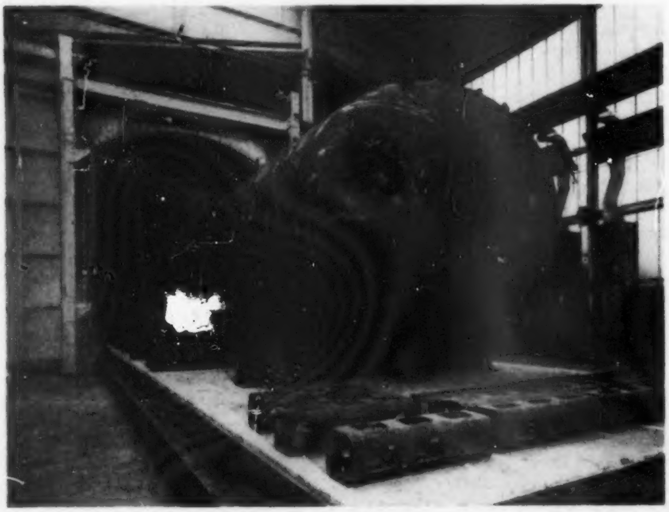
Town's gas is supplied to multiple horizontal and vertical burners located in the base of the side walls to achieve close temperature uniformity. Nozzle mixing is used for the horizontal burners and those firing vertically give luminous flames. Air is provided by a 10-h.p. electrically driven fan.

Temperatures are automatically controlled in six zones, each having a Kent pneumatically operated fully proportioning recording controller. There are three six-point strip chart recorders connected to thermocouples attached to the charge and in the furnace atmosphere. A pressure control instrument is provided and gas consumption is recorded by a flowmeter. All instruments are mounted on a cubicle-type panel.

A. P. Newall & Co. Ltd., Woodside Engineering Works, Possilpark, Glasgow, N.2, announces the appointment of the following representatives: London and South of England, Mr. W. Davis, with headquarters at 19-20 Grosvenor Street, London, W.1; Midlands, Mr. H. Humpston, with his office at 33 Exchange Buildings, Birmingham 2.

Furnace for gas-turbine establishment

G.E.C. (ENGINEERING) LTD. has recently received an order, valued at over £10,000, for a sealed water-quench furnace. It is for installation in the Burnley Works of the Lucas Gas Turbine Equipment Ltd. and it will be used for the annealing and hardening of various types of high-grade steel and steel alloys employed in the aircraft industry.



The 200-ton gas-fired stress-relieving furnace in the Darlington works of Whessoe Ltd. Supplied by Dowson & Mason Ltd. the furnace is believed to be the largest of its type in Europe

Electrical Aids in Industry—Data Sheet **20**

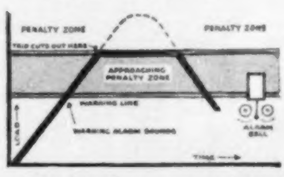
Load Factor Improvement

Most industrial electricity tariffs consist of a fixed charge based on the maximum demand for electricity by the works and a running charge for each unit (kWh) of electricity used. Broadly speaking, the fixed charge covers the capital cost of generating, transmitting and distributing equipment for the particular demand and the running charge covers the cost of generating the units.

Thus, if the factory maximum demand is reduced for the same level of consumption or is held constant for an increased consumption, the cost per unit will be reduced. This is termed improving the 'load factor': load factor being defined as the ratio of the number of units supplied during a given period to the number of units that would have been supplied had the maximum demand been maintained throughout the period; it is usually expressed as a percentage. Some ways in which load factor can be improved are:

CONTROL OF MAXIMUM DEMAND

A maximum-demand alarm gives a warning when the maximum demand is about to be exceeded. One of the simplest devices has two warning contacts, but, as a useful addition, an auxiliary relay can be supplied so that non-essential load can be tripped automatically.



The Load Limiter, an automatic device, meets the requirements of medium and large consumers who wish not only to control their system loading to some target maximum but also to improve the load factor in order to increase the overall economy of the plant.

EXAMPLES OF REDUCTION IN MAXIMUM DEMAND

Broadly speaking, loads which contain some storage element can be transferred from on-peak to off-peak times. Examples are: charging electric batteries used in industrial trucks and road vehicles; pumping loads in drainage schemes; water pumping in quarries, gravel pits and other open-air workings; large cold-storage warehouses; ice-making factories in which cost of power is a sufficiently large item of the operating expense to make a reduced charge acceptable.

Many processes at times of peak demand can, under controlled conditions, tolerate a temporary reduction, or even cessation, of supply without any serious effect on the product. With electro-chemical processes such as in the manufacture of hydrogen peroxide no difficulty arises from periodic interruptions at short or even no notice.

In a plastics factory the management arranged for dies to be switched on by time switches one after another early Monday morning so at the beginning of work all dies had reached their operating temperatures.

In a certain chemical works compressed air is used for blowing out containers for plastic material. The nature of this operation is such that the consumption of air is spasmodic and irregular. The demand-recording meter in this works showed that the 18 kW motor driving the air compressor was frequently cutting in on top of the factory load, thus incurring a higher maximum-demand charge. In this case all that was necessary was to ensure that the air receiver only required charging at night-time or at other off-peak times. It was found that the existing receiver had such a small capacity that the pump had to operate to recharge it almost every time the blowing operation took place. This small receiver was therefore replaced by a receiver of large enough capacity to maintain the blowing requirements over the peak periods without further charging.

For further information, get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, London, W.C.2. Telephone: TEMple Bar 9434.

Excellent reference books are available on electricity and productivity (8/6 each, or 9/- post free)—'Higher Industrial Production with Electricity' is an example.

E.D.A. also have available on free loan in the U.K. a series of films on the industrial uses of electricity. Ask for a catalogue.

7926

CUT HERE

OBITUARY

Edgar Allen & Co. Ltd. regret to announce the death last month, at the age of 67, of **Edwin Gregory,** M.SC.(LOND.), PH.D., A.MET., M.I.CHEM.E., M.I.E.I., F.I.M., F.R.I.C., a director of the company for 15 years and chief metallurgist from 1944 until his retirement from executive duties in March, 1961.

A Sheffield man, resident in Rotherham, Dr. Gregory was known throughout the world for his books on metallurgical subjects and his first book, 'Metallurgy,' published in 1931, is still a standard work in universities and technical colleges in the United Kingdom, the Commonwealth and the United States of America.

Dr. Gregory was a member of the Court of Governors of the University of Sheffield, thus serving his University where he had been a brilliant student and then lecturer in the metallurgical department from 1921 to 1937.

In 1937, he received the freedom of the Sheffield Trades Technical Societies, along with the 'Ripper' medal as a token of distinguished services to the Society and its activities.

During his later life, Dr. Gregory served on many national and local committees. Chief among these were his work as a governor of the National Foundry College, as one of the original council members of the British Iron and Steel Research Association and as chairman of the Standard Methods of Analysis Committee of that Association. He took an important part in the formation of the British Steel Castings Research Association and was a member of its council and Finance Committee as well as Research Committee chairman. He was a past president of the Institution of Engineering Inspection and a former chairman of the Institution of Metallurgists' Examination Committee.

Mr. Robert Davidson MacMillan, managing director of Controlled Heat & Air Ltd. (a member of the Incandescent Group of companies), died last month.

He was born in Glasgow in 1903 and received his technical education at Glasgow Technical College. He served his apprenticeship with A. & J. Inglis Ltd., marine engineers and shipbuilders, and became a qualified marine engineer, and in 1927 joined the Pneumatic Conveyance & Extraction Co. of Manchester and later the Carrier-Owen Engineering Co. Ltd., London.

In 1933 he joined Controlled Heat & Air Ltd. as chief designer and was appointed managing director in 1945. During the period of his office the company and the group with which he was associated have made continuous progress.

Mr. MacMillan concentrated mainly on the lower temperature phase of thermal engineering and contributed substantially to the development of continuous tinplate printing machines, dust extraction in both wet and dry forms, related combustion equipment and heat exchangers and critical control of high-velocity convection in continuous static and mechanized forms.

He was responsible for many technical publications and was a competent lecturer in the subjects in which he was so well versed, and he was well known and liked by a host of industrial friends throughout Britain and overseas.

World's widest aluminium rolling mill

The British Aluminium Co. Ltd. will spend over £10 million on new equipment as an extension to the Falkirk rolling mills in Scotland. The first stage comprises a hot mill, approximately 172 in. wide, which will treble Falkirk's ultimate capacity to 150,000 tons a year. Work will begin immediately and cold rolling and finishing capacity will be increased to absorb the hot-rolling capacity over a succeeding period as the growing market for aluminium warrants. This will be the widest aluminium rolling mill in the world.

500-ton Lombard forging press for India

D. L. Lombard & Sons Engineering Ltd., 19 *Grosvenor Place, London, S.W.1, have recently shipped to India one of their self-contained* 500-*ton Lombard forging presses.*

The press will be installed at the works of India Pistons Ltd., Madras, in one of the world's most up-to-date plants for the manufacture of pistons, piston rings, cylinder liners, gudgeon pins, etc.

This press is very simply operated by means of the hydraulic servo-motor control lever seen on the right which provides rapid acceleration and quick reversal of delivery. This small lever requires only a very light operating force and the ram will retract or lower at a speed depending upon the amount of its displacement from the neutral horizontal position. The maximum return and advance speeds are 740 *in./min. and the pressing speed which commences automatically when ram contacts workpiece is* 76 *in./min. The oil-hydraulic circuit incorporates an Oilgear infinitely-variable-delivery radial piston-type pump giving a particularly smooth action in a compact simple unit. It is driven by a* 150-*h.p. motor.*

Press daylight is 36 *in. with a stroke of* 16 *in. and bolster area of* 36 × 36 *in. The fabricated frame is of rigid construction, giving a bed deflection of less than* 0·001 *in./ft. and allowing for off-centre loading up to a maximum of* 7 *in. from centre when load is evenly distributed on a* 6-*in.-dia. area.*

500-*ton Lombard forging press*

PEOPLE

Mr. H. F. Tremlett, B.Sc., A.R.S.M., F.I.M.

Dr. A. A. Wells, B.Sc.(Eng.), Ph.D., A.M.I.Mech.E.

Mr. P. T. Houldcroft, B.Sc., F.I.M.

The British Welding Research Association announces a number of important changes in its internal administration. Under the new arrangement, the former Welding Process and Resistance Welding sections have been integrated into one Welding Technology Department with wide terms of reference.

Administration of the new department is the responsibility of **Mr. P. T. Houldcroft,** formerly chief metallurgist, who now becomes head of the Welding Technology Department, with **Mr. A. A. Smith,** formerly in charge of the Welding Process Section, as deputy head. Complete administrative responsibility for, and control of, the metallurgical laboratory is assumed by **Mr. H. F. Tremlett,** the deputy director of Research, with **Dr. R. G. Baker** and **Mr. J. G. Young** as chief metallurgists in charge, respectively, of ferrous and non-ferrous researches.

Work in the physics of the electric arc, including the development of techniques for controlling and utilizing ultra-high temperature arc plasma, and in the development of electronic control and monitoring systems, will be under the control of **Dr. A. A. Wells,** the assistant director of research, who also controls the Association's engineering researches.

The British Iron and Steel Research Association has appointed **Mr. A. G. Shakespeare,** M.A.(CANTAB.), as head of its steelmaking laboratories at the Sheffield research station. At the time of this appointment Mr. Shakespeare was in charge of the Association's work on hot strip processing at the Sketty Hall laboratories in Swansea.

Aged 33, Mr. Shakespeare was educated at Garw Grammar School in South Wales and Fitzwilliam House, University of Cambridge, where he read for the Natural Sciences Tripos, obtaining a second-class honours degree in metallurgy in 1951.

From 1951 to 1952 he was employed at the research laboratories of Fairey Aviation, where he worked on the heat treatment of light alloys and precision casting techniques. He then moved to the Nelson research laboratories of the English Electric Co., where his special interests were X-ray crystallography and the high-temperature 'cermet' materials.

In 1954 he joined BISRA and has since been engaged in research into the design and operation of strip processing plants, playing a notable part in the development of the Association's new rapid continuous annealing process.

Mr. Kenneth A. Smith, who for the past two years has been a director of Firth Cleveland Steel Strip Ltd., of Tipton, Staffs., has been appointed a director of Firth Cleveland Steel Ltd. and of the associated company, J. J. Habershon & Sons Ltd. He will have full executive responsibility over the whole field of steel strip production and will be based at Holmes Mills, Rotherham.

Mr. Smith joined the Tipton Co. in 1949 as a metallurgist. In 1955 he was made works manager and in 1959 he became production director.

Following the recent resignation of **Mr. A. M. Simmers,** who has taken up an appointment with Vickers Ltd., **Mr. P. H. Morwood** is appointed secretary of English Steel Corporation Ltd., and **Mr. A. Taylor,** special director, is appointed chief accountant.

Mr. P. H. Morwood is also secretary of the U.K. subsidiaries of the E.S.C. Group, and Mr. A. Taylor is chief accountant of the wholly owned subsidiaries.

Mr. Vernon H. Willey has been appointed by Firth Cleveland Steel Ltd., of Rotherham, Yorks., to a special post with the company as marketing manager (stainless steels).

Mr. Willey's immediate responsibility will be to acquaint users and potential users of stainless-steel strip throughout the country with the new sales policy adopted by J. J. Habershon & Sons Ltd.

Since 1958, Mr. Willey has been director and general manager of the Edmonton Steel Strip Co. Ltd., London, N.8, and he will continue to hold these appointments.

Mr. Mervyn A. Fudge has been appointed director

and general manager of the Tenuous Steel Co. Ltd., of Rotherham, Yorks., by Firth Cleveland Steel Ltd. Since 1956, he has been company secretary of Firth Cleveland Steel Strip Ltd., of Tipton, Staffs., manufacturers of wide hardened and tempered strip in carbon and alloy steels. For the time being he will still retain this position.

Firth Cleveland Steel Ltd. looks after the marketing interests, both at home and overseas, of the Tenuous Steel Co. Ltd., Firth Cleveland Steel Strip Ltd., J. J. Habershon & Sons Ltd., and the Edmonton Steel Strip Co. Ltd. All five companies are members of the Firth Cleveland Group.

Mr. Martin Lyth, M.A., A.M.I.MECH.E., has recently been appointed director of supplies to Griffin & George (Sales) Ltd. This is a new post created to meet the growing need for the buying and allied functions to be represented at board level. Until his new appointment Mr. Lyth was managing director of Griffin & George (Scientific Instruments) Ltd., a subsidiary company which manufactures the Griffin specialist range of scientific instruments.

Mr. Lyth was born in 1919 and educated at Newcastle-under-Lyme and Clare College, Cambridge. He began his engineering career as an aerodynamicist in Sir Frank Whittle's firm, which was pioneering the jet engine. After the war he moved to design and thence to production, and spent seven years as a management consultant with Production Engineering Ltd. He joined Griffin & George in 1957 and became managing director of the production subsidiary in 1958.

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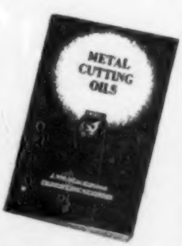

Informative literature is available on request

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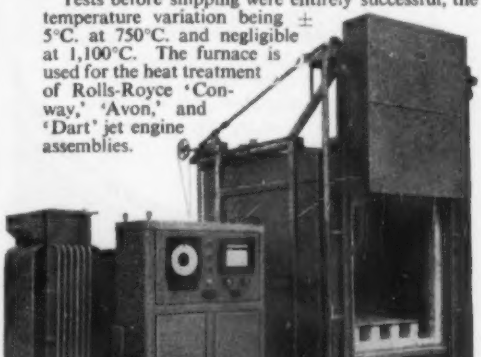

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